TOPOGRAPHIC AND GEOLOGIC SURVEY COMMISSION OF PENNSYLVANIA

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Topographic and Geologic Survey
of Pennsylvania

RICHARD R. HICE, State Geologist

Report No. 9.

Minerals of Pennsylvania

BY
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AND
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TOPOGRAPHIC AND GEOLOGIC SURVEY COMMISSION

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LETTER OF TRANSMISSION.

To the Topographic and Geologic Survey Commission:—

Gentlemen:—I have the honor to transmit herewith the Manuscript and Illustrations of a report on the Minerals of Pennsylvania, prepared by Dr. Amos P. Brown, with the assistance of Dr. Frederick Ehrenfeld, and recommend its publication as Report No. 9.

The preparation of this report was authorized in response to a demand for a brief account of the useful minerals of the State, and those most likely to prove of value, with references to the localities where the same are known.

This report does not pretend to be an extensive and complete account of any of the various minerals of the State, but presents in brief such information regarding them as will prove of immediate value, and form the basis of a more extended study by those especially interested in any particular lines. Relatively brief mention is made of coal, both anthracite and bituminous, each of which will require many times the entire space given to this report, but the short general statement concerning coal will be found of interest.

More detail is given to some of the more important of the mineral products, concerning which less is generally known.

It is believed this report will prove of value in all parts of the State, being in the nature of a guide to our vast mineral wealth.

Respectfully submitted,

RICHARD R. HICE,
State Geologist.

January 31, 1913.

INTRODUCTION.

The years passed since the conclusion of the Second Geological Survey of Pennsylvania have shown no cessation in the mineral industry of the State. On the contrary the extension of exploitation and the activity of the miner, clay worker, quarryman and builder have made vast increase in both production and consumption of our mineral wealth.

What this wealth really is it may be well to allow disinterested persons outside the State to say. We quote from the United States Geological Survey Press Bulletin of December, 1912.

"PENNSYLVANIA LEADS IN MINERALS."

"Pennsylvania far outranks all other States in the value of its mineral output. In 1911 this State contributed, exclusive of pig iron, 24.7 per cent. of the total mineral output of the United States. The reason for Pennsylvania's undisputed leadership lies primarily, according to the United States Geological Survey, in its great production of coal. It is almost exclusively the source of anthracite, and produces over one-third of the total bituminous [illegible]. [illegible] ranks second, next to New York, in the value of its [illegible], and stands first as a mineral producer in cement, coal, coke, [illegible] mineral paints, sand and gravel, and building stone."

This report is an attempt to collect into a somewhat compact form the important details of this vast mineral wealth. It is not intended to be a technical report for the expert alone but is designed as far as possible to be read by those not acquainted with the details of technical language and while it is not possible in all cases to avoid the use of such language it is hoped that it may be the means of giving useful information to our citizens and afford them some means of finding out what our mineral wealth is, and where to look for the same. Also, it is designed to show where certain forms of mineral deposits are probably not to be found; this is in some respects as important as knowing where they can be had, as too often persons are lead into unprofitable expenditure of money by looking for mineral deposits where there is no probability of their existence. This is not always possible to avoid, but in the main the sources of our mineral wealth are already outlined in occurrence and any further increase in production is more likely to be obtained by the careful conservation of what we now have, than by the discovery of new deposits.

It can not be too strongly impressed upon the consuming public, as well as upon the producer, that "eternal vigilance" is as much the price of wealth and energy as it is said to be of liberty. Our mineral resources, vast as they are, are not after all inexhaustible and it is a matter of the utmost importance that we "take stock" of what we now possess, consider the best and most economical means of mining it, quarrying it or using it with the least possible amount of waste. When we consider that the whole vast fabric of modern industrialism is entirely dependent upon energy derived, in practically all cases, from coal, and that the coal supply is not of endless amount, it seems only a matter of common prudence to mine and use our coal with the most careful consideration.

Yet as an actual fact there is enough illuminating gas or power producing gas wasted in our coke ovens in one day to light, heat and supply with power many a large American municipality for an entire week. It would seem to be advisable to have some sort of a State investigation as to what means may be best devised to conserve the mineral wealth of our State and to preserve or prolong its life as much as possible. For many of the details of this Report we are under especial obligation to the State Geologist who has taken a constant interest in its preparation.

ABRASIVES.

The qualities which make a mineral or rock valuable for abrasive or grinding purposes are first of all *hardness,* and in addition, habits of breaking known among mineralogists as *fracture* and *cleavage.* These differ from each other in that cleavage is a manner of breaking in certain exact, definite directions in accordance with the natural laws of crystal growth, whereas fracture is breaking in no definite shape or flat surface. A common manner of fracture as seen in quartz, for example, is in rather wavy, rounded, concentric surfaces known as *conchoidal fracture;* whereas the gem diamond, while the hardest known substance, breaks along cleavage lines in very definite directions.

The value of cleavage and fracture in abrasives is that because of them the mineral substance presents under use a succession of fresh surfaces and cutting edges, this is notably the case with garnet.

Corundum wheels have to be sharpened somewhat, for though this substance is harder by several points than garnet, it is also tougher and does not cleave or fracture as readily. If the mineral is hard and the grains break in such a manner that instead of becoming rounded good cutting edges are kept exposed, the abrasive efficiency is high. This efficiency is measured by the amount of abrasion upon a given surface in a given time. Minerals are judged as to hardness by a definite scale of ten. This is aside from the cleavage or breakage. The diamond is the hardest natural substance known, but it also is somewhat easily broken. The softest is number one.

SCALE OF HARDNESS.

No. 1—Talc, (soapstone).
" 2—Gysum.
" 3—Calcite.
" 4—Fluorite.
" 5—Apatite.
" 6—Orthoclase feldspar.
" 7—Quartz (flint, agate, chert).
" 8—Topaz.
" 9—Corundum (ruby, sapphire).
" 10—Diamond.

Some garnets are said, for example, to have "a hardness of 7.5"; this means harder than quartz but not so hard as topaz which is 8.

The natural abrasives found in this State are *Buhrstones* and *Millstones*, both forms of sandstone or quartz rock.

Grindstones—sandrock.

Garnet. Hardness, 6 to 7.5.

Quartz, in crushed or ground state; Hardness, 7.

Fledspar. Hardness, 6.

Corundum ("emery"). Hardness, 9.

LOCALITIES IN PENNSYLVANIA.

Buhrstone is a term applied to rocks which are usually coarse grained sandstones, or conglomerate; other rocks known as chert are also called buhrstones.

Above the Vanport limestone (which see for locality) lies at times a flinty layer known as buhrstone. The production in Pennsylvania is small.

Grindstones, Millstones are made up of natural quartz rock (sandstone or conglomerates), with enough strength of body to stand the wear and tear of grinding. The Carboniferous standstones of Western Pennsylvania and the massive sandstones of the Medina formation are used. Near Milroy, Lewistown and other old communities in the Kishacoquillas Valley of Mifflin County there were a few years ago, when the locality was visited by one of the writers (E), a number of flour mills using millstones said to have been made from the sandstones (Medina) of the Seven Mountains near by.

Millstones are produced at present at East Earl and Lincoln, Lancaster County.

Emery is not produced in this State but corundum is; the other materials used as abrasives are described under their several heads. *Polishing* and *grinding* sands are made from quartz, feldspar, corundum, hematite (jewellers' rouge); sands for polishing glass are found in some of the river beds in the western part of the State, (see under Sand). Crushed sandstone is also used for the same purpose.

ALLANITE.

This is one of the so-called "rare earth" minerals, that is, those which carry cerium, yttrium, lanthanum, etc.; it has some radio activity and has attracted some attention on that account.

It is a silicate of lime, aluminum and iron with the rare earth minerals named above and has been suggested as a possible material from which to make mantels similar to the Welsbach type.

Allanite is a markedly heavy mineral with a bright pitch black or brown color. When found loose in the soil it is coated with a brown crust.

It has been found in Pennsylvania, at Allentown; at Pricetown, near Reading; at Bethlehem, in East Bradford and Coventry townships, Chester county; at Frankford, Philadelphia. Nearly all localities are granitic rock.

The following analyses are from Genth's Rep. B. p. 80.

	East Bradford.	Princeton.	Bethlehem.
Sp. gr.,	3.535	3.831	3.491
Silicic acid,	31.86	32.39	33.31
Alumina,	16.87	12.49	14.34
Ferric oxide,	3.58	7.33	10.83
Ferrous oxide,	13.26	9.02	7.20
Manganous oxide,	....	0.25	....
Cerous oxide,	21.27	15.68	13.42
Lanthana, } Didymia, }	2.40	10.10	2.70
Lime,	10.15	7.12	11.28
Magnesia,	1.67	1.77	1.23
Soda,	....	0.09	0.41
Potash,	....	0.14	1.33
Water,	1.11	2.49	3.01
	101.17	99.37	99.06

AMAZON STONE. (See feldspar.)

AMETHYST. (See quartz.)

AMPHIBOLE AND PYROXENE.

These are mineral silicates of magnesium and iron which are sometimes of individual importance as in the case of Asbestos, which is a variety of Amphibole.

Anthophyllite is another variety of Amphibole which occurs at times also in a fibrous form. The rocks known as diabase, gabbro and in general as "traps" contain pyroxene, in consequence of which they are very tough and hard to break, as is the case with practically all varieties of Amphibole and Pyroxene.

A bright vivid green variety of amphibole sometimes called *smaragdite* is found at Mineral Hill, near Media, in Delaware county; smaragdite is sometimes used as a gem. While these amphiboles and pyroxenes are of great mineralogical interest they are seldom of much individual importance, in any commercial way, except as above noted.

Hornblende, a black or dark green variety of amphibole, is a prominent mineral in some of the older gneisses and schists; it is found also in association with magnetite and hematite iron ores and their adjacent rocks in some of the South Mountain ore deposits. It is not, however, to be taken as an indication of iron.

APATITE. (See phosphate minerals.)

ASBESTOS.

Two different minerals are used under the name Asbestos, the one is a fibrous variety of a mineral known as Amphibole, a magnesium silicate, Mg_3Sio_3, containing no water.

The other is a fibrous variety of serpentine known as *Chrysotile,* which is a magnesium silicate chemically united with water, $H_4Mg_3(Sio_3)_2$.

In the blow pipe flame the fibres of amphibole will fuse to a clear glossy bead; the chrysotile blackens and crumbles or may sinter slightly to a black mass.

There are three commercial types of asbestos—*cross fiber, slip fiber* and *mass fiber*—distinguished by the form of the mass. The most valuable asbestos fiber occurs in cross-fiber veins. The fiber runs directly across the vein from side to side. Its length is thus limited by the width of the vein and ranges from one-sixteenth of an inch to two inches. For the most part the veins of asbestos separate easily from the country rock and when broken across expose the fluffy asbestos fiber with the sheen of silk. Slip fiber occurs along slipping planes or faults and shows the direction of the motion. Most of the slip-fiber asbestos is of low grade.

All asbestos is of secondary geological origin, and it may be derived by alteration from a variety of rocks generally rich in magnesium silicates. Some of it, however, is derived from impure dolomite limestone. Rocks originally rich in the magnesium silicates are by far the most important source, they alter to serpentine and under favorable conditions give rise to asbestos. The purer the serpentine the more likely it is to contain asbestos. It is claimed for the chrysotile that it is less likely to contain grit than the amphibole, it is also tougher than the amphibole asbestos; it is the common commercial variety.

USES.

Asbestos is, of course, well known through its heat resisting qualities and because of this it is used largely for fire-proofing and for packing material around steam and other pipes. It is also manufactured into boards, sheets and paper for domestic uses and for use around electrical wiring. In the powdered form it is used as a filler for paints as in *Asbestine.* Mixed with cements, magnesia, plaster of paris and similar substances, it is made into a considerable variety of special shapes.

While not now commercially produced in this State it has been found in a number of places, some of which have been in the past producing localities. Various places in Chester, Delaware, Lehigh, Lancaster, Montgomery and other counties have shown the Amphibole variety. It was formerly mined near Rockdale, Delaware county,

where it occurs in quartz veins. At Mineral Hill, near Media, and at the soapstone quarries at Lafayette it also occurs.

Chrysotile in beautiful silky masses has been found near Easton, it has been found also in Upper Providence, Radnor, Marple, and other townships in Delaware county.

In general it maẏ be looked for throughout the sepentine district.

AZURITE. (See copper.)

BARITE; BARYTES.

Barite, barium sulphate ($BaSO_4$), called "Heavy Spar," is a heavy crystalline mineral, white when pure, and is very stable in relation to acids, alkalies, or corrosive gases. It is usually more or less iron stained and associated with clay, silica, calcium carbonate, and other minerals when mined, so that it has to be ground, washed, and bleached with acid to purify it.

If a small fragment be fused strongly in a hot gas flame the flame is colored a pale yellow-green; this is a good practical test to distinguish between barite and celestite, (the sulphate of Strontia), which under flame tests gives a crimson flame.

LOCALITIES IN PENNSYLVANIA.

Barite is found in this State in the Lower Helderberg limestone (Lewistown limestone) in Blair, Fulton and probably other counties; in the Cambrian in Adams (?), Franklin and to the east of the Susquehanna River. In Franklin county it is found in brecciated limestone at the Snobarger farm two miles N. E. of Waynesboro; also at the Lindsay farm, the Stamey farm, the Bonebreak farm, all in the vicinity of Chambersburg. The general average runs 95.91 to 98.65 percentage of barium sulphate. It is usually found as heavy white lumps when plowing is being done. (U. S. G. S. Folio 170, 1910, p. 18). It is found in Bucks county at New Hope; at the Phoenixville mines, Chester county; at Perkiomen and Jug Hollow mine, Montgomery county; it occurs also with the marble at Marble Hall; at Fort Littleton, Fulton county; at Heidleberg, Berks county; in Sinking Valley, Blair county, and at New Brighton, Beaver county, along with Siderite (carbonate of iron), (Genth). McCreath gives analyses of Blair county barite (Rep. M. 2, p. 369, Penna. Sec. Geol. Survey.) The percentage of barium sulphate ranges from 95.91 to 98.65, no strontia present. The same authority gives analyses from the Silas Locke farm near Fort Littleton, Fulton county, which show 95 or 96 percentage barium sulphate and no strontia. It is found also in the "Chert vein" in the Oriskany sandstone at Orbisonia, Huntingdon county; (Genth Rep. B. p. 238, 1875.) Barite, like

Fluorspar, is at times associated with lead ores. In this State it is generally dug or plowed up loose in the soil. At Pineville, Berks county, it occurs in a vein two feet or more wide and was once opened under the idea it was limestone, it is in Trias red shale.

USES OF BARITE.

"By far the greater part of the barytes produced is consumed in the ground, or ground, floated, and bleached state in the manufacture of mixed paints. It is not satisfactory as a pigment if used alone in oil, for its crystalline nature renders it too transparent to give good hiding power, and it must be used in only moderate percentages in mixed paints which consist principally of the lead and zinc-white pigments in order that advantages may be secured by its use. Its use as an adulterant in white lead, or in any other pigment or commodity, is not legitimate, and should be discouraged by the producers. There are sufficient legitimate uses for this valuable mineral to create a healthy market for it if properly handled. Barytes is used also in the manufacture of lithopone, a very white pigment that is suited most particularly for interior use, in the manufacture of enamels and wall finishes. In the manufacture of lithopone barytes is first reduced from the sulphate to the sulphide of barium, and then treated with zinc sulphate. Zinc sulphide and barium sulphate, intimately mixed, is the result, forming lithopone. Barium sulphate is also obtained in the precipitated form (blanc fixe) which is used as a base on which lake colors are precipitated. Barium salts are reported to be used in brickmaking in order to overcome the efflorescence of bricks.

Other uses for barytes are in the manufacture of rubber, wall paper, asbestos, cement, poker chips, and in tanning leather." (U. S. Geological Survey).

BERYL. (Emerald, Aquamarine.)

Beryl is a silicate of alumina with the rare element beryllium: glucinum. When somewhat pale blue to green it is the gem aqua marine, when a brilliant green and transparent it is known as emerald. While not a common mineral in Pennsylvania it is apt to be met with in the feldspar veins as short stumpy six-sided prisms of a pale green or yellowish color. The Jefferis collection, now in Pittsburgh, and the Cardeza collection, now in the University of Pennsylvania, have some very large specimens; in the latter are some six to eight inches thick and eighteen or more inches long; these are not of good quality of color. Probably the best have been found along Crum Creek from Swarthmore to Chester and vicinity, in some places these are of fair gem (aquamarine) quality as to color, though small and full of cracks. Beryl is also met with in Germantown, Olney and other places in or near Philadelphia county.

Golden Beryl has been found in good gem quality at the Avondale quarries near Swarthmore.

BIOTITE (See mica.)

BLUESTONE. (See sand, sandstone.)

BRICK.

Bricks of all sorts are made in Pennsylvania.

For *ganister brick* see under silica. *Sand-lime bricks* are made near Hummelstown, Dauphin county, from brownstone in part. Bricks from clay are made at very many localities throughout the State; for *shale brick* see under shale. *Refractory bricks* of many kinds are in especial demand in this State for coke ovens, steel furnaces, blast furnaces and other forms of apparatus needing high grade refractory casings or linings; added to this the demand for structural (building) purposes makes the number of bricks produced in this State almost past count.

Magnesite and *chromite bricks* are made from material obtained outside the State.

Blast furnace and other slags have been used at various times to make bricks; also to make "slag-tile" for roofing and paving purposes.

BROMINE. (See potash and salines.)

BROWNSTONE. (See under silica, sand.)

BRUCITE. (See magnesia minerals.)

BUHRSTONE. (See abrasives.)

BUHRSTONE ORE. (See iron ores.)

CALCITE. (See limestone.)

CALAMINE. (See lead and zinc.)

CEMENT MATERIAL.

See under *limestone* for the Lehigh and other cement rocks. *Clay* for white cement is dug at Mt. Holly Springs, Cumberland county.

Blast furnace slag is used for cement, it is obtained mostly from Pittsburgh and vicinity.

CHALCOCITE.

CHALCOPYRITE.

CHROMIUM MINERALS.

Chromite or Chrome Iron.

Chromic iron ore is widely distributed through areas of serpentine and associated basic rocks in different parts of the United States. Such areas have been found in a few localities in the old metahorphic rocks east of the Appalachian region from New England to Georgia; at various points in the Rocky Mountain region; throughout the extent of the Sierra Nevada and Coast Ranges in California, and at a few points in the Cascade Mountains. It is not found in the usual sedimentary rocks except in some gravels and sand.

The main uses are in making pigments and paints from "chromates," in tanning leather; chromium compounds are used to some extent in making special alloys for steel such as *ferro-chrome,* and for other alloys such as "chromax bronze." *Pyrophoric* alloys used in pocket cigar lighters are made from chromium in part. The ore chromite is used for refractory furnace linings.

Chromite in Pennsylvania is found practically contiguous with the Serpentine belts in Lancaster, York, Chester, Delaware, Bucks, Lehigh and other counties.

In appearance the Chromite is black, shiny like pitch and by the unexpert is often mistaken for *Pitch Blende,* an ore of "Radium." It is heavy, hard, and when crushed or rubbed on quartz or porcelain forms a pale to dark brown colored powder depending on the hardness of the sample. At present it is not produced commercially in the State but has been mined, notably at the old Wood Mine at Texas, Lancaster county, and at mines in Elk, East Nottingham, West Nottingham townships in Chester county.

The small streams and sands and gravels in the Serpentine districts are often full of shiny black 8-sided crystals of the Chromite and Magnetic iron. It would be tedious to enumerate the reported localities.

Analyses of Pennsylvania Chromite (Report B, p. 43, Penna. Second Geological Survey.)

	1	2	3	4
Sp. gr.,	....	....	4.568	4.780
Chromic oxide,	51.56	60.836	63.384	53.36
Alumina,	9.72	0.928	....	5.98
Ferric oxide,	....	38.952	38.663	7.41
Ferrous oxide,	35.14	....	....	26.64
Niccolous oxide,	....	0.100	2.282	0.14
Cobaltous oxide,	....	....	....	trace.
Manganous oxide,	....	....	....	0.39
Magnesia,	....	....	....	6.53
Silicic acid,	2.90	0.619	....	....
Total,	99.32	101.435	104.329	100.45

1. Chester Co. Ore, analyzed by Seybert.
2. Chester Co. Ore, octahedral crystals, analyzed by Starr.
3. Woods Mine Ore. Massive, analyzed by Garrett.
4. Chromite crystals from Hibbard's farm, Media, analyzed by Genth.

There is of course the possibility that more modern methods of prospecting would show valuable deposits of the ore in the Serpentine districts. The chief localities reported are in the vicinity of Media and Mineral Hill, Marple, Blue Hill, Hibbards farm, Fairlamb farm, and Palmer's Mill, all in *Delaware county.*

In *Chester county* along the Octororo creek, in West Goshen township near West Chester, in Williston township; in *Lancaster county* in the general locality of Wood's Chrome Mine and extending out from there to the Octororo and south into Maryland. This belt is also said to run over into *York county*, where Chrome ore is reported.

A number of mines have been opened in Chester county in addition to the places above given; they are practically all in the "White Barrens" of East and West Nottingham townships. In Delaware county mines were formerly worked at Marple and in Middletown townships. There is a good supply of chromite in many of the Pennsylvania mines but it is not as good in quality as the ore from Asia Minor which is now imported in large quantity.

CHRYSOCOLLA. (See copper.)

CHRYSOTILE. (See asbestos.)

CLAY.

This is one of the most valuable of the mineral sources of wealth in Pennsylvania. It is not possible to do more in this report than touch briefly on certain aspects of the subject leaving the final consideration of clays in this State to later and more detailed study.

Clay is a natural material of very wide occurrence. It has also a great variation in color, compactness, manner of occurrence, and use. It generally possesses or may be made to acquire the property of plasticity, by which it may be molded into a great many shapes and then baked or burned to a permanent form.

COMPOSITION OF CLAY.

Clay is generally said to be made up essentially of the mineral *kaolinite,* a silicate of aluminum, chemically united with water, thus $H_4Al_2Si_2O_9$, or 2 $H_2OAl_2O_32SiO_2$; in which the Alumina is 39.5 per cent. Other common materials which may be present in clays are silica sand, coarse and fine; oxides and hydrates of iron, manganese and titanium; carbonates of lime, magnesia and iron; the alkalies, soda and potash, and often a considerable quantity of undecomposed fragments of minerals such as feldspar, garnet, mica and tourmaline. Phosphoric acid and organic matter are sometimes present, together

with a variable quantity of water in addition to that chemically united in the kaolinite.

Physically, clay as it is actually found in nature may be a mixture of an indefinite amount of kaolinite with any or all of the above impurities so that it is not possible to give a definition of clay which will cover all cases either from the point of use or of occurrence and diversity of character. In a broad sense, however, it may be said that the term clay has come in actual practice to mean a natural plastic substance, or one which may be made so artificially by grinding and mixing with water, and other materials and capable of being subsequently baked or burned in a kiln into permanently hard forms. This excludes substances such as cement and concrete which harden or "set" without burning in a kiln after molding.

This conception of clay includes a considerable number of plastic substances which are possessed of very little or no kaolinite. This is a subject concerning which there has been a great deal of discussion and it is possessed of some importance as it is considered by many authorities to be impossible to state in all cases that a substance used and spoken of as clay consists essentially of kaolinite or even contains it.

The truth seems, however, to be that some intimate union of alumnia, silica, and water is not only actually found in the high grade clays but is present up to at least ten per cent. of alumina in practically all other clays which are in actual use. *Adobe* and *loess* with as little as three per cent. Al_2O_3, are used however for brick making.

ORIGIN OF CLAY.

Clay is what is known among geologists as a secondary rock or mineral substance, that is, it is formed by the chemical and physical alteration of some other mineral aggregate which is in the majority of cases the so-called crystalline rocks of the type of granite, pegmatite, mica-schist, "trap," etc. These crystalline rocks are prevailingly made up of minerals which are aluminous. The alteration from the original rock to clay is the result of decay and transformation of mineral matter (formed previously under the action of pressure or heat) into a new series of minerals which at the surface of the earth do not change further or decompose. The "clay" of the geologist is the final product of this rock decomposition where there are compounds of alumina, silica and water present; and as such a final product clay is not subject to further rotting or decay. It is upon this in part that the value of clay depends. Inasmuch as most rocks contain iron and other ingredients, it often happens that their alteration into clay is accompanied by the simultaneous formation of other natural products which occur as impurities in the clay. These have been mentioned above.

PLATE I.

B.—Upper surface of the limestone after the clay has been removed to make brick. The knob of limestone is about six feet high. Photograph by F. Ehrenfeld.

PLATE I.

A.—Residual limestone clay dug for brick in a quarry at York, Pa. This clay is formed by sub-aerial decay of the limestone. Photograph by F. Ehrenfeld.

RESIDUAL CLAYS.

Sedimentary (transported) Clays.

This clay material upon formation may accumulate as a residue in practically the same spot as the original rock from which it has been formed, or it may be washed by rain into streams and transported long distances from its place of origin; it may even eventually be carried out to sea and deposited on the ocean floor. The first of these types of clays, those occuring at the point of origin, are known as "residual clays;" those of the second type are known as "sedimentary" or "transported clays." The *kaolins* of the Brandywine district in Pennsylvania are examples of the first type, as are also the "limestone clays" of many places and the clays of the Great Valley in part. Fire clays, the red brick river clays as in Washington and other counties, and shales which are clays compacted into hard rock form, are examples of the second type. Beyond these two fundamental types the classification of clay becomes very complex, depending upon the view from which the subject is approached, such as commercial use, mode of occurrence, chemical character, or some particular quality as plasticity or fusibility.

The reason for this state of things lies in the exceedingly diverse nature and quality of the clays themselves; the same kind of clay from the point of view of use will in different localities occur in totally different ways, while clays of a like method of occurrence will be found to vary so widely in value as to make exact classification almost impossible.

Classification of E. Orton Sr., (Ohio Geo. Sur. Vol. VII., P. 52

		Uses.
High Grade Clays. (50% or more of kaolin), not over 5% fluxing impurities.	1. Kaolin(ite), ...	Manufacture of fine ware.
	2. China clay, ...	Manufacture of fine ware.
	3. Porcelain clay, ...	Manufacture of fine ware.
	4. Fire clay (hard), ...	Refractory materials.
	5. Fire clay (plastic), ...	Refractory materials.
	6. Potters' clay, ...	Earthenware, etc.
Low Grade Clays. Kaolin from 10% to 70% with notable percentages of fluxing impurities. Sand often conspicuous.	1. Argillaceous shale, ...	Paving block.
	2. Ferruginous shale, ...	Pressed brick.
	3. Silicious clays, ...	Paving block, sewer pipe.
	4. Tile clays, ...	Roof tile, drain tile.
	5. Brick clays, ...	Pressed brick.
	6. Calcareous shale, ...	Common brick.

USES OF CLAYS.

Clays are used for so many different purposes that a complete enumeration of these is not practicable. However, the uses may be grouped as follows:

1. The manufacture of pottery and porcelain.
2. The manufacture of paving material.
3. The manufacture of pipe and hollow ware.
4. The manufacture of refractory materials, furnace brick, etc.
5. The manufacture of building material.
6. Minor uses; these include
   clays for paint filler.
   clays for paper filling and sizing.
   clays for scouring soap.
   clays for medical ointments and plasters.
   clays for plaster cement.
   Alum shales or clays for making alums by leaching with sulphuric acid, and many other purposes.

Simple Tests Useful in Prospecting for Clay[1].

"1. A small lump of clay may be roasted in a blue gas flame, as in a gas stove; if a red or brown color be given to the clay, the percentage of iron is high, probably 4 per cent. or more. Fire clays are low in iron.

"2. By tasting a bit of the clay, bitter salts, alum and epsom, may be detected, or they may occur as a white coating on the outcrop of the clay in the bank. These salts are apt to form whitewash coats on the finished brick, injuring the appearance. By crushing the clay in the mouth the sand may be detected by the grit against the teeth. A rough determination of the amount of such sand may be made.

"3. A good test for pottery clay is moistening the clay and finding whether it can be worked into definite shape and retain the form without cracking when dry.

"4. A rough brick of small size can be made and easily dried, and a rough determination be made of its shrinkage. If it shrinks out of shape, cracks or crumbles when dry, its value is very doubtful. For this test the clay should be ground, thoroughly tempered with water, and dried slowly.

"5. If carbonates of lime are present, a few drops of hydrochloric acid (muriatic) may be added, and they will be detected by the effervescence or bubbling as the carbonic acid gas passes off. A better plan is to place a lump of clay in the small amount of acid, as the clay absorbs the liquid so rapidly that the effervescence may be overlooked. Good fire bricks are low in lime.

"If there be low percentage of iron present and a higher percentage of lime (about three times the iron) the clay product will burn buff. If the high percentage of lime be due to lumps of lime carbonate, the brick on burning will crack and warp. Very high percentages of lime are apt to ruin the clay. It is not always possible to predict the

1. West Va. Geol. Sur. Vol. 3, p. 90, 1905.

color of the burned ware from the color of the clay. Red clays will usually burn red; blue clays may burn red of buff. Dark or black clays are usually high in organic matter and may burn red or buff.

"6. The slaking of clays or the crumbling down in tempering is tested by dropping a lump of clay in a cup of water. Some clays slake in a very few minutes and so are easily tempered. Shales slake usually only after a long time and require fine grinding."

ANALYSIS OF CLAY.

There are two ways of expressing the composition of a clay from the exact chemical standpoint. One is what is known as the utimate analysis, the other as the rational analysis. The respective characters of these two methods will be illustrated by examples of Pennsylvania clays. First it may be said that the ultimate analysis of a clay is designed to show the amount of the essential constituents silica, alumnia, and water (SiO_2, Al_2O_3 and H_2O) present, as well as the various impurities. The impurities in part act in fluxing or fusing the clay when baked in the kiln. Others are inert or are objectionable and must be removed.

The ultimate analysis of a clay may be expressed as consisting of certain percentages of the following chemical materials:

	Name.	Chemical Formula.
	Silica,	SiO_2
	Alumina,	Al_2O_3
Fluxing Impurities	Ferric oxide,	Fe_2O_3
Fluxing Impurities	Lime,	CaO
Fluxing Impurities	Magnesia,	MgO
Fluxing Impurities	Alkalies, potash,	K_2O
Fluxing Impurities	Alkalies, soda,	Na_2O
	Titanic oxide,	TiO_2
	Sulphur trioxide,	SO_3
	Carbon dioxide,	CO_2
	Water,	H_2O

The rational analysis has as its purpose the stating of the different minerals which may be present in a clay such as quartz, feldspar, kaolinite. and is particularly valuable in the case of the high grade porcelain and china clays. This is really the most important method of analysis from the practical view.

These points may be shown as follows:

Kaolinite when pure has the following composition:—

Silica, SiO_2,	46.50
Alumina, Al_2O_3,	39.50
Water, H_2O,	14.00
	100.00

which is a definite mineral of the formula $H_4Al_2Si_2O_9$. Compare this with the analysis of a kaolin from the Henry Clay mine, Cumberland Valley District, Pa.

Ultimate Analysis.

SiO_2,	73.30
Al_2O_3,	17.43
Fe_2O_3,	0.37
CaO,	0.02
MgO,	1.28
K_2O,	2.99
Na_2O,	0.17
H_2O,	4.68
	100.24

Rational Analysis.

Clay,	56.75
Feldspar,	.54
Sand (flint),	37.17
H_2O,	5.54
	100.00

This shows a marked variation from the ideal composition of a kaolinite in its high percentage of silica and the lower percentage of alumnia. The rational analysis is then an attempt to restate the composition of a clay in terms of the actual minerals present, which in this case are kaolinite, the clay base; silica (flint), and feldspar.

Other analyses of Pennsylvania clays show these two kinds of analyses.

Analysis of Flint Clay from Mercer shales, South Fork, Pa.[1]

	SiO_2,	44.30
	Al_2O_3,	38.31
Fluxing Impurities,	Fe_2O_3,	1.40
	FeO,	0.71
	MnO,	0.10
	CaO,	0.82
	MgO,	0.59
	Na_2O,	0.22
	K_2O,	0.17
	SO_3,	trace
	H_2O 100°,	.75
	Ignition loss,	12.17
		99.64

Rational Analysis.

Free alumina,	3.88
Clay subs.,	93.26
Feldspar,	2.86

DIFFERENT KINDS OF CLAY.

The exact classification of clay has already been referred to, but, aside from that, clays as commonly found in use may conveniently, though roughly, be grouped as follows, beginning with the highest grades:—

1. Kaolin and china clay.
2. Ball-clay.
3. Fire clay { Plastic / Non-plastic (flint or rock clay).

[1] U. S. Geol. Surv., Folio 174 (Johnstown), p. 12.

4. Pottery and stone ware clays.
5. Paving brick and sewer-pipe clays.
6. Tile clays.
7. Terra cotta clays.
8. Common brick clays.
9. Drain tile clays.
10. Shales, of which there are very many grades and kinds, used mostly for shale-brick, pressed brick, paving brick, etc.
11. Slip-clay, a term applied to those which at a low kiln temperature fuse easily to a self-glazing surface, due to the high percentages of fluxing elements present. Slip-clays or self-glazing clays are not much used at present, but in former times were used in Pennsylvania in many small kilns to make domestic articles, especially in the eastern part of the State.

The term *Kaolin* is not always used as exactly as might be desirable. It is however generally considered to include the clays which are essentially residual; which burn white, are free of fluxes or nearly so, and on analysis work out to nearly pure silica, alumina and water in a chemical union. The impurities present are apt to be free quartz and incompletely disintegrated feldspar or mica.

Kaolins often pass gradually downwards into the parent rock which has been their source. The following analyses show the character of kaolins:—

	(1)	(2)	(3)
SiO_2,	46.26	62.40	47.71
Al_2O_3,	36.25	26.51	36.78
Fe_2O_3,	1.64	1.14	....
CaO,	0.19	0.57	....
MgO,	0.32	0.01	....
K_2O,	1.69	0.98	2.58
Na_2O,	0.85		
H_2O,	13.54	8.80	13.03
Total,	100.74	100.66	*100.10

*Moisture 0.25.
[1]T. C. Hopkins, Min. Ind., vol. 7, p. 160. Kaolin from Brandywine Summit, Del. Co., Pa.
[2]Webster, N. C. Crude kaolin. N. C. Geol. Survey, Bull. 13, p. 62.
[3]Coussac, Bonneval, France. U. S. Geol. Survey, Prof. Paper 11, p. 39.

KAOLIN IN PENNSYLVANIA.

Kaolin is used in the trade under several meanings. It here is used for the commercial forms of kaolinite. It is a high grade clay, sometimes residual and at other times a transported clay. It is nearly always washed before use to remove sand and coarse material. The chief uses are for china-ware and as a filler in paper making.

Chemical Composition of Pennsylvania Kaolins[a].

	SiO_2.	Al_2O_3.	Fe_2O_3.	CaO.	MgO.	K_2O.	Na_2O.	H_2O.
1,	67.71	20.53	7.78	0.39	0.04	0.29		3.12
2,	46.26	36.53	1.64	0.19	0.32	1.69	0.85	13.54
3,	51.90	31.29	......	trace	1.52	4.01	2.99	8.90
4,	84.05	9.44	0.28	0.23	1.35	2.37	0.28	2.18
5,	73.80	17.30	0.35	......	1.18	2.49	0.20	4.69
6,	73.30	17.43	0.37	0.02	1.28	2.99	0.17	4.68
7,	67.10	20.10	3.90	1.10	0.70	2.00		5.90

1 Brandywine Summit.
2 Brandywine Summit.
3 Glen Lock.
4 Mount Holly Springs, crude.
4 Mount Holly Springs, refined.
6 Henry Clay mine, refined.
7 Chestnut Hill.

Paper Clay. The essential requirements for a good paper clay are white or nearly white color, slaking or falling apart readily in water, remaining in suspension in the pulp, and freedom from grit. The clay is added to give weight to the paper and a good surface for printing.

China or Porcelain Clay. For these purposes the purest kaolins are needed. This clay is generally mixed with "flint" (powdered quartz) and feldspar for the purpose of changing the fluxing point and modifying the shrinkage.

DISTRIBUTION OF PENNSYLVANIA.

Pennsylvania kaolins[1] may be divided into two distinct groups, viz: the Delaware and Chester county kaolins, practically all residual deposits formed from the decay of pegmatite (giant granite) veins and the South Mountain kaolins in Cumberland, Adams, Franklin, and York counties. These deposits are practically all residual from the destructive weathering of slates or schist rocks, and this residue then transported and deposited as sediments. They are more extensive in area than the Chester-Delaware deposits.

One of the oldest clay producing localities in the State is that near Kaolin P. O., Chester county, which has been worked since 1839. At Hockessin, Delaware, three miles from the above are similar deposits.

Brandywine Summit, Delaware county, has been noted for many years as a locality for high grade kaolins. There are practically two companies controlling these deposits, which are worked also for ground feldspar. Near Elam P. O., near to Brandywine Summit, is a deposit of white clay used in part for fire brick, as is also some of the Summit clay. The best of all these clays have been shipped in the past to the potteries of Ohio and New Jersey. Several by-products are worked from these deposits. These are silica sand screened from the kaolin and used for porcelain clay-mixing or for refractory brick.

a From "Kaolin," T. C. Hopkins, Mineral Industry, Vol. 7, p. 148.
1 See article by T. C. Hopkins, Mineral Industry, Vol. VII, 1898, pp. 156.

About one and a half miles north of Glen Lock Station on the north side of Little Chester Valley, is situated a more recent kaolin mine. The clay is on the contact line between the Chester Valley limestone, Cambrian, and the North Valley Hills (Cambrian?) sandstone. This kaolin has a striking resemblance to the deposits of the South Mountain district.

THE SOUTH MOUNTAIN CLAYS.

These are sedimentary and appear to be at the top (or near it) of the Cambrian sandstones, shales, and limestones. Those familiar with this general region will of course recall that some years since iron ore openings were frequent and in practically all these mines clays were found in rather large amounts. These clays are at times very much stained with the iron, at other times the pure clay exists in large quantities. These deposits have not on the whole been given the attention they deserve as there are undoubtedly large quantities of clays suitable for fire and paving brick, stoneware, tile and pipe ware, and other uses.

The clays occur both above and below the iron ores as the strata are much folded and otherwise disturbed. Formerly in mining the ore the clays were often thrown out and have been mixed with lower grades. A careful search through the district mentioned would probably yield valuable results in the way of better grades of kaolin. At the following localities, however, the clays have been worked. Very extensive developments have been worked south of Mount Holly, on the Gettysburg and Harrisburg Railroad, and on the Hunter Run and Slate Belt branch.

The Mount Holly deposits are among the thickest and purest of the South Mountain clays. They are at times quite siliceous as shown in the subjoined analysis by W. T. Schaller[1].

SiO_2,	69.61
Al_2O_3,	16.83
Fe_2O_3,	0.95
CaO,	0.11
MgO,	1.51
Na_2O,	.08
K_2O,	3.41
P_2O_5,	.14
TiO_2,	.90
Loss on Ignition,	6.35
	99.89

The Pennsylvania Tile Works started about 1892 a plant at Aspers. Clay washing plants have been worked at Latimore, Pine Grove, Dillsburg, and Laurel Station. A large clay working plant including washers and refiners, by-product machinery, kilns, etc., was opened in 1898

[1] U. S. Geol. Survey, Folio 170 (Mercersburg-Chambersburg), p. 18.

at Mount Holly Springs, Adams county. The clay lies at Upper Mill Station and Hunter Run. At Maple Grove, south of Mertztown, Berks county, occurs a clay used for kalsomine.

These South Mountain clays have been used for wall paper, pottery, tile, fire brick, and the screenings also have been utilized as material for fire brick or as mixer for pottery making.

OTHER RESIDUAL CLAYS IN PENNSYLVANIA.

These might occur at almost any point in the State south of the glacial districts. In many of the limestone valleys of the great mountain regions of the State occur deposits of clay, residues from the decay of the limestones and shales of the higher ground. These have in many cases been washed down into the lower valley places and are in part transported clays suitable for brick or tile. The chief localities, however, for the better grades of the residual clays must be sought in the southeastern portions of Pennsylvania, owing to the occurrence there of the older feldspathic rocks which are the source of the best clays. In the old ore banks of the Lehigh-Berks districts are deposits of white clay. Variegated clays are common in Lancaster and York, red residual clays are known in Penn township, Chester county. In the Great Valley district are great quantities of white and variegated clays derived largely from decay of schists and often mixed with the residues from the decomposition of limestones, quartzites, slates, etc., of the Ordovician or Cambrian ages. The composition of one of these clays from the Hunter Mine, Kemp farm, is as follows:

Analysis of Clay from Hunter Mine.[1]

Silica (SiO_2),	66.17
Alumina (Al_2O_3),	19.89
Iron protoxide (FeO),	0.783
Lime (CaO),	0.26
Magnesia (MgO),	1.902
Alkalies (K_2O), (Na_2O), etc.,	6.211
Water (H_2O),	4.784
	100.000

Residual Clays are most largely produced in the following counties: Adams, Berks, Blair, Chester, Cumberland, Delaware, Lancaster, Lehigh and York.

SURFACE OR PLEISTOCENE CLAYS.

Drift Clay; River Clay; Terrace Clay. These are clays which grade more or less into each other in maner of occurrence and character. They are often referred to as *Surface* or *Pleistocene* clays. In Pennsylvania they may occur in nearly all parts of the State. As a class they are rather impure and sandy and are frequently used for common brick making, though where they are homogeneous and pure

[1]Ries, U. S. Geol. Survey, Prof. Paper 11, p. 209.

enough they may be used for making pottery. The drift clays or moraine clays are to be looked for in the northern parts of the State above the line of the glacial moraine. They are irregular in occurrence, often stony, though at times they are represented by fine grained clays, known as bowlder clays, which are whitish, reddish, or blue in color. In the valleys of the Ohio, Beaver, Allegheny, and other rivers and streams in the western part of the State, are to be found occurrences of these glacial drift clays laid out in terrace form. These are known as "terrace-clays" and are used for making terra-cotta, flower pots, bricks, and so on. Analyses of these terrace clays from New Brighton, Pa., have been published[1] by A. S. McCreath as follows:

	(1)	(2)
Silica, SiO_2,	46.160	67.780
Alumina, Al_2O_3,	26.97	16.290
Sesquioxide of iron, Fe_2O_3,	7.214	4.570
Titanic oxide, TiO_2,	.740	0.780
Lime CaO,	2.210	0.600
Magnesia MgO,	1.520	.727
Alkalies,	3.246	2.001
Water H_2O,	11.220	6.340
	99.286	99.088

These are high in fluxes as may readily be seen and hence are used for vitrified wares. These clays are found on the fourth terrace above the bed of the Ohio River.[2]

Alluvial Clays, those found along beds of rivers in the flats and river banks are very common and of great use, particularly for the making of bricks. These clays occur east along the valleys of the Delaware and other streams and are the source of much of the highly famous "Philadelphia pressed brick." In the western part of the State practically all the river valleys supply large quantities of brick clay. Along the Monongahela River flats these clays have been worked for many years as at Monongahela, California, and Charleroi in Washington county, and similarly in Allegheny, Armstrong, Beaver, Fayette, Greene and Westmoreland counties.

Fire Clay. This term, like kaolin, has unfortunately come to be used in popular speech erroneously. Properly speaking the term "fire clay" means a material which will resist fire or heat. The most important single character of fire clays is refractoriness, which means in this case, or should mean, fusion at a point not less than 3000° F. (1650° C.) or thereabouts. Fire clays are usually low in fluxing and coloring impurities; become white upon calcination, and in short are high grade clays and belong properly speaking among the kaolins as to refractory character. Fire clays are frequently, though not necessarily, of sedimentary (that is transported) origin, and hence popular conception has taken all of the clays which underlie the coal beds as fire-clays, irrespective of whether or not they are refractory. If some

[1]Second Geol. Survey of Pa. Rep. M. 2, p. 257.
[2]These clays are related to the earlier Kansan or pre-Kansan drift, and not to the deposits of the last, or Wisconsin ice invasion. (R. R. H.)

limit of refractoriness is not used upon fire-clay, the term will become meaningless. Fire clays are divided into two sorts, non-plastic clays known commonly as *flint-clay,* and *plastic* fire-clay. The flint clays often show a very hard character which is increased by air drying, and break with semi-circular fractures like pitch or glass, and even on thorough grinding show little or no plasticity. The plastic fire clays do not differ necessarily in appearance from other clays which are plastic, but chemical analysis shows a practical approximation to kaolin and they are of equal value for refractory quality.

CHEMICAL COMPOSITION OF FIRE CLAY.

Fire clays contain in an exact chemical analysis traces or appreciable quantities of the elements usually shown in an ultimate analysis, such as the fluxing elements, magnesia, lime, iron and alkalies; excess of quartz, that is silica not chemically combined with alumina and water, may be present. If this silica is high, even with low amounts of fluxing elements, the clay upon heating may fuse and come in strict classification outside the limits of refractory clays.

Flint clays in a rational analysis show usually a high content of clay substance (kaolinite) with free quartz, free alumina, or free feldspar, the last in small quantities, 1 to 2 per cent. The following analysis *by Lord of a clay from the Lower Kittanning of Ohio (Mineral Point clay) shows the character of flint fire clay of great excellence, with very low fluxing content:

Combined silica,	35.39
Alumina,	31.84
Combined water,	11.68
Percentage kaolinite base,	78.91
Free silica,	17.13
Titanic acid,	1.68
Sandy material (total),	18.81
Sesquioxide of iron,	0.67
Lime,	0.50
Magnesia,	0.19
Potash,	0.59

The Physical Properties of fire-clays show a wide range in plasticity, color, shrinkage, texture, hardness, and so on. The color of a fire clay may run from white and light yellow through reds and browns to black. The black or dark grey color of many so-called fire clays from under the coal beds is not a definite indication of a refractory clay, since the dark color, due in part often to organic matter, may cover up the iron fluxing elements present. Nearly all Pennsylvania fire clays are located under coal beds and derive their names from these well known coal beds. Refractory clays in Pennsylvania are found also in the Cambrian and Ordovician (Silurian) formations of the southeastern part of the State. They are found often as the decomposition products from schists, slates, and limestones.

*Ohio Geol. Survey, vol. 7, p. 66.

off pieces of any size. After being out in the weather a long time it tends to become more brittle, so that a sharp blow with a heavy hammer on a block a foot cube may break it into a hundred pieces, but each little piece has all the sharp edges and the conchoidal faces of a piece of quartz flint broken down under similar conditions. The geologist unacquainted with the rock hardly hesitates to call it limestone on general appearance until he has tested it with acid.

The rock is not all of the high grade described, either chemically or physically. The lower figure of Plate II is from a photograph of a specimen of what is known as nodular clay. This as a rule will make brick of only second grade. Flint clay, as is well known, is non-plastic, and must be mixed with a certain percentage of plastic clay in order to be moulded into bricks. The percentage of plastic clay varies according to the use to which the fire brick is to be put, or the grade of fire brick being made, and also with the refractory qualities of the plastic clay. The occurrence of flint clays is a matter that has been but little discussed in reports or text books. In some cases the flint clay occurs as a deposit sharply delimited by rocks of quite different character, but it usually occurs associated with shales and clays somewhat similar in physical aspect. In some cases the limits of the two associated deposits are sharply drawn. In other cases they are not. In some cases it would appear to be an original deposit in the regular sequence of layers; in others it would appear to be a secondary alteration deposit."

Analyses of Selected Specimens of Flint Clays, Kaolinite and Indianaite.

	1	2	3	4
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Silica (SiO_2),	42.700	43.350	44.550	46.4
Alumina (Al_2O_3),	37.600	37.550	39.000	39.7
Iron oxide (Fe_2O_3),	2.385	2.145	1.440	....
Titanium oxide (TiO),	2.500	2.825	1.700	....
Lime (CaO),	.112	.084	.028	....
Magnesia (MgO),	.270	.234	.072	....
Alkalies,	.730	.235	.530	....
Water and organic matter,	13.840	14.170	13.660	13.9

	5	6	7	8
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Silica (SiO_2),	44.75	46.75	44.60	43.19
Alumina (Al_2O_3),	38.69	38.17	40.65	41.60
Iron oxide (Fe_2O_3),	.95	.29	.80	....
Titanium oxide (TiO),	....	....	....	....
Lime (CaO),	.37	.57	.27	.15
Magnesia (MgO),	.30	.12	....	.06
Alkalies,	.35	.07	....	.45
Water and organic matter,	15.17	14.03	14.23	13.48

Nos. 1 to 3, upper, middle and lower portions of bed $2\frac{1}{2}$ miles west of Blue Ball, Clearfield county, Pa. (McCreath, Second Geological Survey of Pennsylvania, volume II, page 121). No. 4, theoretical composition of kaolinite; No. 5, composition of indianaite, Lawrence county, Indiana (Noyes); No. 6, flint clay, Carter county, Ky.; No. 7, Gaylord flint clay, Sciota county, O.; No. 8, Stone City flint clay, Stone City, Ky. (Nos. 5 to 8, Twenty-ninth Ann. Rept. Dept. of Geology, Natural Resources Indiana, 1904, p. 392). The indianaite is a pure white deposit of a hydrous aluminum silicate. It occurs at the base of the coal measures in Indiana, and apparently has a somewhat similar origin to the flint clays. The Carter county, Ky., clay is probably from Olive Hill. It is a matter of some interest that the Olive Hill clay, as does that from Sciotaville, also occurs at the base of the coal measures. In that part of Kentucky and Ohio it there underlies the massive Sharon sandstone or conglomerate just as the indianaite underlies the massive Mansfield sandstone or conglomerate of approximately or quite the same age. The matter is of interest as suggesting the possibility of a closer relation ship between the indianaite and flint clays than is suggested by the analyses alone."

TRANSPORTED OR SEDIMENTARY CLAYS IN PENNSYLVANIA.

The geological formations of the State range from the Pleistocene sands and clays along the Coastal Plain; the glacial and late non-glacial sands, gravels, and clays of the northern counties of the State, and of the streams and rivers both east and west; through the great series of rock formations, the Carboniferous, Devonian, Silurian, Ordovician, Cambrian and the altered, crystalline slates and schists of older origin. While rocks of a general clay character may be found in practically all of these series of formations it is in the Carboniferous series that the great clay deposits are found. It is not practicable to consider these in detail in this report. Clay is found under practically every coal bed in the State, some of this "clay" is in reality shale in the strict sense of the term and represents a wide range of physical, and chemical differences.

The Pottsville carries the Sharon and Mercer clays, correlated with the very valuable Mt. Salvage clays of Maryland.

The Allegheny carries a number of clays, some of which are among the most valuable mineral resources of the State; from the bottom up these are:—Brookville, Lower Clarion, Upper Clarion, Lower, Middle, and Upper Kittanning Clays, Lower Freeport, Bolivar, and Upper Freport.

The Conemaugh is characterized rather by shales than clays; these are worked for *shale brick.*

The clays of the upper portions of the coal measures are but little exploited, the "main clay" of the Pittsburgh bed, 8 inches thick is worked at Courtney and Manown for forms for Open Hearth and Bessemer steel furnaces. (Pa. Geol. Survey.)

Practically all the plastic clays are from the Allegheny and Pottsville.

The Conemaugh carries a flint clay worked at Layton, and also the Lower and Upper Mahoning clays in Lawrence, Beaver, Clearfield, Cambria, Indiana and Jefferson counties, and elsewhere.

"*Mt. Savage Fire Clay (Mercer).* The lowest fire clay, and one of the best, if not the best in the State, occurs in the Mercer group of coals. It has long been worked at Mt. Savage, Maryland, and the clay from that point has established a deservedly fine reputation. In Pennsylvania it has probably been longest and most extensively mined in Clearfield county. It was for a long time mined on Sandy Ridge in Centre county, but the works there now are supplied from near Burly in Clearfield county. It is extensively worked at Woodland and in the region west of Blue Ball, around Burly, and between Burly and Blue Ball. It is found widely scattered all over the upland made by the McCartney anticline between Clearfield creek and the Pennsylvania Railroad to the east, as well as west of Clearfield creek. West of Clearfield syncline the coal is brought up again, and is mined in a large way west of Curwensville, west of Stronach, and at many points up Anderson creek on both sides. It also occurs in the valley of the west branch of the Susquehanna for several miles above Curwensville. As usual the clay is irregular, sometimes reaching a thickness of up to 18 feet, but more often being only 6 feet or less. In places the clay is all flint, and in others the flint clay runs out altogether. There is usually some soft clay with the hard clay, generally overlying, but often both above and below the hard clay. Over the soft clay is the Mercer coal, which runs from a few inches to 2½ feet. In general, the analyses of these clays as obtained by McCreath show from 44 to 46 per cent. of silica, 34 to 39 per cent. of alumina, 1.8 to 3.5 of iron oxide, 0 to 2.5 of titanium oxide, 1.06 to 3.02 of lime, .126 to .573 of magnesia, .830 to 5.75 of alkalies, and 4.885 to 14.170 of water.

This clay is mined at St. Charles and Climax, on Red Bank creek in Clarion and Armstrong counties, where analyses indicate as high a grade of clay as in Clearfield county. At St. Charles the clay as a whole has a thickness of from 8 to 10 feet, the flint clay varying as usual with the soft clay. At Climax the bed is 12 feet, composed of flint and soft clay in varying proportions. As a rule the flint clay makes up about one-third of the bed. From its position low down in the series this horizon has a very limited outcrop in the area under discussion."[1*]

[1*] Top. and Geol. Survey Commission, Report of 1906-08, p. 322.

While the chemical analyses of a clay does not definitely determine its value, the following tables, showing the composition of clays from a number of localities, will be of value.

Analyses of Brookville Clays.

	1	2	3	4	5	6	7	8	9	10
SiO_2,	45.42	45.65	44.95	45.82	74.95	42.7	43.35	44.55	46.25	45.45
Al_2O_3,	36.80	34.73	37.75	35.95	15.94	37.6	37.55	39.00	37.50	36.125
Fe_2O_3,	3.33	3.546	2.70	3.03	1.849	......	......	......	......	......
FeO,	......	......	......	......	......	2.385	2.145	1.44	1.935	2.275
MnO_2,	.48	......	......	......	......	......	......	......	......	......
CaO,	.87	.112	.302	.112	.106	.112	.084	.028	.168	.168
MgO,	.45	.619	.216	.573	.407	.270	.231	.072	.126	.342
Alk,	......	5.75	.985	4.13	1.756	.73	.237	.53	1.115	1.29
H_2O, }	12.65	9.65	13.05	10.13	4.885	13.84	14.17	13.66	13.51	13.73
Org, }										
TiO_2,	......	......	......	......	......	2.50	2.825	1.70	......	......
SO_3,	......	......	......	......	......	......	......	......	......	......
FeS_2,	......	......	......	......	......	......	......	......	......	......

	11	12	13	14	15	16	17	18	19	20
SiO_2,	45.23	46.18	44.45	44.045	58.125	60.675	78.075	64.83	68.49	......
Al_2O_3,	38.03	36.88	38.945	39.445	26.5	25.915	14.41	23.95	18.46	......
Fe_2O_3,	1.98	2.25	......	......	......	......	......	......	......	......
FeO,	......	......	2.135	.94	3.234	2.21	1.59	.9	1.566	......
MnO_2,	......	......	......	......	......	......	......	......	......	......
CaO,	.163	.173	.173	.075	.078	.069	.056	.11	.23	......
MgO,	237	.317	.155	.115	.555	.465	.48	.187	.551	......
Alk,	.830	2.76	.76	.72	2.18	1.925	1.67	.296	2.755	......
H_2O, }	13.605	11.58	13.287	14.138	9.725	9.09	4.163	9.39	6.31	......
Org, }										
TiO_2,	......	......	......	......	......	......	......	.88	2.15	......
SO_3,	......	......	tr.	tr.	.058	tr.	tr.	......	......	......
FeS_2,	......	......	......	......	.008	......	......	......	......	......

1.—Fire clay, Johnstown, Cambria County, Second Pennsylvania Geol. Surv. Rept. HHH, pg. 147.
2—Fire clay, Sandyridge, Clearfield County. Top layer used for furnace bottoms.
3—Second layer, same locality. Used for bricks.
4—Third layer, same locality. Used for tiles and inwalls of furnace.
5—Bottom layer, same locality. Sandy and not used; 2 to 5 feet thick. Indem. Rept. H, p. 119.
6—Upper or "Shell clay" from shaft of Harris Firebrick Co., 2½ miles west of Blueball. Ibid., page 121.
7—Middle or Block clay, same place. Ibid.
8—Lower or "Flag clay," same locality; 6 to 8 feet. Ibid.
9—From south side of Roaring Run Brook, near Woodland Station. Ibid 123.
10—North side of Roaring Run Brook, three-fourths mile west of Woodland Station. Bed 4 to 5 feet hard clay. Ibid, page 123.
11—Hard clay, one-half mile southeast of Hope Mine. Ibid., pg. 121.
12—Soft clay, one-half mile southeast of Hope mine. Ibid.
13—Fire clay from Jones mine, between Benezette and Trout Run mine, Lycoming county. Ibid. pg. 134.
14—Hard fire clay. E. Fletcher & Brother, two miles west of Benezette. Ibid. pg. 135.
15, 16, 17 } Fire clay. Newsome. Ibid pg. 225 (from Brookville, Pa.)
18—Upper clay } Blacklick, Indiana county.
19—Plastic clay } Indem. Rept. HH, pg. 194.
Above table of analyses quoted from *Ries Prof Paper No* 11. U. S. Geol. Survey, pp. 220-221, 1903.

Analyses of Lower Kittanning Clays.

	1.	2.	3.	4.	5.	6.
SiO_2,	61.970	61.750	62.890	62.260	66.610	56.670
Al_2O_3,	22.940	23.660	21.490	23.890	18.390	26.560
FeO,	1.818	1.930	1.818	1.408	1.964	2.106
TiO_2,	1.975	1.780	1.825	1.780	2.810	1.790
CaO,	.440	.455	.380	.470	.490	.260
MgO,	.522	.353	.569	.309	.547	.277
Alkalies,	1.750	2.418	2.525	1.977	1.079	3.790
H_2O (hygroscopic),	1.480	.680	1.160	7.640	7.495	8.360
H_2O (combined),	7.370	7.200	7.580			
	100.265	100.226	100.237	99.731	99.385	99.813

	7.	8.	9.	10.	11.	12.	13.
SiO_2,	57.670	60.190	61.980	68.920	56.37	61.86	67.50
Al_2O_3,	27.520	24.230	23.880	22.380	29.62	26.02	25.70
FeO,	1.491	2.097	1.395	.980	*1.14	.63	3.76
TiO_2,	2.540	2.345	1.830	....	....	....	....
CaO,	.380	.850	.040	.190	.45	.19	.60
MgO,	.122	.036	.281	.172	.14	1.26	1.55
Alkalies,	.619	1.669	2.677	....	1.08	.31	....
H_2O (Hygroscopic),	9.680	9.015	7.820	6.140	1.92	9.98	Loss.35
H_2O (combined),	....	....	....	....	8.71		
	100.025	100.432	99.903	98.782	99.43	100.25	99.46

*As sesquioxide.

1 to 4.—From Elverson & Sherwood's mines, near New Brighton, Beaver County, being, respectively, first, second and third grades of clay and the raw clay. Analyses by D. McCreath. Second Geol. Survey Pennsylvania, Rept. MM, p. 262.

5.—Mendenhall & Chamberlin mines, near New Brighton, Beaver County. Analysis by D. McCreath. Ibid.

6—Coale's clay, near New Brighton, Beaver County. Analysis by D. McCreath. Ibid.

7—Couch's clay, New Brighton, Beaver County. Analysis by D. McCreath. Ibid.

8—Severn's clay mines, near Vanport, Beaver County. Analysis by D. McCreath. Ibid.

9—S. Barnes & Co.'s clay, Bridgewater, one mile north of Rochester, Beaver County. Analysis by D. McCreath. Ibid.

10—Brady Run Fire Brick Company, Beaver County. Analysis by F. G. Frick. Mineral Resources U. S. for 1896; Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 5 (continued), 1897, p. 1155.

11—Flint clay from Mineral Point. Analysis by N. W. Lord. Geol. Survey Ohio, vol 7, 1893, p. 221.

12—Haydenville, Ohio. Analysis by E. M. Reed. Geol. Survey Ohio, vol. 7, p. 139.

13—Average of six analyses made for Vanport Brick Company, Vanport. Analyses by Hunt & Clapp, Pittsburgh Testing Laboratory.

Analyses of Lower Kittanning Clays Near Johnstown, Pa.[1]

	(1)	(2)	(3)	(4)
SiO_2,	65.90	66.40	53.10	68.82
Al_2O_3,	20.30	19.80	27.80	20.85
Fe_2O_3,	*1.60	*1.68	*3.08	2.79
MgO,	0.66	0.61	0.60	0.23
CaO,	0.09	0.10	0.22	0.82
Na_2O,	0.34	0.30	0.48	....
K_2O,	2.98	3.24	3.58	....
TiO_2,	1.20	1.00	1.20	....
MnO,	....	....	....	0.06
Loss on ignition,	6.50	6.40	10.20	5.83
Totals,	99.57	99.53	100.26	100.00

*Total iron calculated as Fe_2O_3.

[1]U. S. Geol. Survey, Folio 174, p. 13, 1910.

PLATE III.

A.—View of Kittanning Clay Manufacturing Company's Works at Kittanning.

PLATE III.

B.—View of Kittanning Clay Manufacturing Company's Quarry at Kittanning.

Analyses of Bolivar Fire Clay or Upper Freeport Limestone Clay.

	1	2	3	4	5	6	7	8	9	10
SiO_2, ...	59.830	51.920	47.250	40.720	60.520	55.330	55.680	56.780	65.370	52.230
Al_2O_3, ...	24.580	31.640	34.350	37.280	21.970	27.841	29.180	26.890	24.870	31.310
FeO, ...	1.655	1.134	0.693	2.448	1.650	2.916	0.837	0.322	0.756	1.008
TiO_2, ...	1.170	1.160	1.990	2.280	1.220	1.140	1.490	*	*	1.680
CaO, ...	0.280	0.030	0.580	0.520	0.910	0.580	0.130	0.369	0.168	0.130
MgO, ...	0.872	0.443	0.090	0.002	trace.	0.756	0.180	0.987	0.234	0.165
Alkalies, .	3.114	0.402	0.261	0.570	0.218	3.916	0.245	3.920	0.010	0.720
Water, ...	7.830	13.490	13.695	15.002	9.395	7.495	12.490	8.380	8.790	13.190
CO_2, ...	....	none.	0.455	0.408	0.725	0.455	....	....	....	....
Total,	99.331	100.219	99.364	99.230	99.608	100.429	100.232	100.548	100.378	100.433

*Not determined.

References for Analyses of Bolivar Fire Clay or Upper Freeport Limestone Clay.

1—E. Robinson's clay deposit in Indiana County 2nd Geol. Surv. Rept. HH, p. 90.
2—Kier Brohters, Salina, Bell Township, Westmoreland County; flint clay. Idem. Rept. 115, p. 114.
3—Kier Brothers' clay, Salina; top stratum, hard and brittle. Ibid.
4—Kier Brothers' clay, Salina: middle stream, hard and brittle. Ibid.
5—Kier Brothers' clay, Salina; bottom stratum. Ibid.
6—Kier Brohters' clay, Salina; plastic clay. Ibid.
7—R. Hall's, near Laughlinstown, 4 miles east from Ligonier, Westmoreland County. Idem. Rept. K3, p. 219.
8—Furnace clay on Jacob's Creek, 2 miles southeast of Jacobs Creek Station. Idem. Rept. L., p. 112.
9—Forge clay on Jacobs Creek, 2½ miles southeast of Jacobs Creek Station. Ibid.
10—George Potter's clay on Meadow Run, south of Ohio Pyle Falls, Fayette County. Idem. Rept. K3, p. 219.
Above analyses quoted from U. S. Geol. Surv., Professional Paper No. 11, by H. Ries.

THE COAL FIELDS OF PENNSYLVANIA.

The geological formations which carry the coals of this State are prevailingly found in that portion of the Carboniferous known as the *Pennsylvanian.* These coal bearing rocks contain both the anthracite and bituminous coals and in popular language are often called *"The Coal Measures"* collectively.

The Permian Period, above the Pennsylvanian, contains some few coal beds locally important, but which in comparison with the coals beneath are of minor value.

These geological formations carrying the coals are as follows:

Permian, ...	Dunkard formation	Upper Barren Measures
Pennsylvanian, ...	Monongahela formation	Upper Productive Measures
	Conemaugh formation	Lower Barren Measures
	Allegheny formation	Lower Productive Measures
	Pottsville formation	

The Permian carries practically no beds worked at present. Most of the coal now mined comes from the Allegheny and Monongahela series. *The Pottsville* carries the Sharon and Mercer coals, worked only in restricted areas in the western part of the State, and the Upper and Lower Lykens coals in the anthracite fields in the east. The above table applies more particularly to the bituminous coals rather than to the anthracite as attempts to correlate the two series of coals are not very satisfactory and the succession of the beds in the anthracite fields is not clear. However the *Allegheny* is believed to carry the Buck Mountain in the anthracite region and the *Monongahela* the Mammoth, Holmes, etc., in the same field.

General Statement. Coal has always been the largest single mineral resource of Pennsylvania. In a preliminary statement on the coal production of Pennsylvania in 1907 the Division of Mineral Resources of the U. S. Geological Survey states as follows regarding coal in Pennsylvania:

"Until 1902 Pennsylvania produced each year more than half the coal mined in the United States, but since then the State's output has fallen below one-half, by reason of the great increase in production in other States.

"Pennsylvania produces more coal than any other single State or country in the world except Great Britain, having in 1907 exceeded for the first time the production of Germany. Pennsylvania's production of coal exceeds, in fact, the combined production of all foreign countries except Great Britain and Germany."

The anthracite region is found in an area of somewhat more than 480 square miles and covers parts of the counties of Carbon, Columbia, Dauphin, Lackawanna, Luzerne, Northumberland, Schuylkill, Sullivan, Susquehanna, Wayne and Wyoming in which last there is no coal mined. The most important producing localities at present are in the counties of Carbon, Lackawanna, Luzerne, Northumberland and Schuylkill. The coal areas included in these counties have been grouped into four or five so-called fields owing to the fact that the coal beds are found in a nearly parallel series of elongated basins running in a northeast-southwest direction.

The Lykens or Pottsville Coals. Concerning these coals David White makes the following observations (20th Annual Rept. Pt. 2d, U. S. Geol. Survey, 1900. "The Stratigraphic Succession of The Pottsville Formation"). "It will be observed that in the section of the Pottsville Formation at the gap south of Pottsville a number of thin coals are present, several of them having been prospected in the vicinity of the typical locality. Coals are to be found in varying numbers in every complete section of the formation, though in the neighborhood of the type section they have not proved to be of a profitable thickness. However, to the north of Pottsville, on Broad Mountain, and to the west, throughout the southern field, coals occur in greater development, especially locally, and have been extensively mined. These coals of the Pottsville formation, which are commercially known as the "Lykens" coals, and which comprise the "Lower Red Ash" groups of the southern field, appear to be best developed or most advantageously exploited in the districts west of Tremont, including the Lincoln region and the Wiconisco Basin.

"In the anthracite fields, as well as in the other coal fields of the Appalachian trough, the combustible of the Pottsville formation is generally the most valuable of the entire series of Carboniferous coals; for, while as individual beds the Pottsville coals may be inferior in

thickness and areal extent, their superior qualities create for them the highest demand and encourage their production even under conditions entirely unfavorable for the exploitation of other and thicker beds. To this formation belong the Sharon coal of Northern Ohio and Northwestern Pennsylvania; the Pocahontas and New River coals of Virginia and West Virginia, celebrated as steam and coking coals; the chief coal horizons of Eastern Tennessee; the coals of Georgia; and the principal furnace and steam coals of Alabama. The special fitness for domestic use of the rather free-burning Lykens coals, which wins for them an advance of from 25 cents to $1.25 per ton over the prices of other coals of the anthracite series, has resulted in the establishment in the Lincoln-Lykens region of several of the largest mining plants in the anthracite fields, the capacity of the Lincoln and Brookside collieries, which are exclusively occupied with the Lykens coals, being 2,900 tons a day of ten hours."

"Analyses of the West Brookside coals made by Dr. Cresson in 1879 show":

Anthracite Coal Fields, by Field, Local District. and Trade Region.

Volatile matter,	5.4
Ash,	8.78
Sulphur,	0.36
Phosphorus,	none
Fixed Carbon,	85.636

A tabular statement of the several sections of the anthracite fields is given below.

Coal Field or Basin.	Local District.	Trade Region.
Northern,	Carbondale, Scranton, Pittston, Wilkes-Barre, Plymouth, Kingston,	Wyoming.
Eastern middle,	Green Mountain, Black Creek, Hazleton, Beaver Meadow, Panther creek,	Lehigh.
Southern middle,	East Schuylkill, West Schuylkill, Lorberry, Lykens Valley,	Schuylkil.
Western middle,	East Mahanoy, West Mahanoy, Shamokin,	Schuylkil.
Western northern,	Bernice Basin,	

The above table, except Bernice Basin, from U. S. Geol. Survey, Min. Res. Pt. II, 1910.

Bituminous Coal bearing rocks cover practically the whole of Allegheny, Armstrong, Beaver, Blair, Butler, Cambria, Greene, Indiana, Jefferson, Lawrence, Washington and Westmoreland counties; the greater portion of Clarion, Elk, Fayette, Mercer and Somerset counties; and parts of Bedford, Blair, Bradford, Cameron, Center, Clinton, Crawford, (not mined), Forest, (not mined),

Fulton, Huntingdon, Lycoming, McKean, (not mined), Tioga and Venango, (not mined), counties. Chief producers are Allegheny, Butler, Cambria, Clearfield, Fayette, Indiana, Jefferson, Somerset, Washington and Westmoreland counties.

Coal of valuable quality is produced from the *Broad-Top* region, in Bedford, Fulton and Huntingdon counties; the beds worked are Kelly, Barnet and Fulton. The Pittsburgh bed is present in five small, high knobs. The Broad-Top field is under study by the State Survey and a special report on it will be issued later.

From data furnished by the State Geologist it is estimated that the production of bituminous coal alone is practically 500,000 tons per day, the output of Fayette and Westmoreland counties alone being a million tons a week.

THE BITUMINOUS COAL FIELDS.

The Allegheny formation carries the following workable coals, named from the bottom up: Brookville, Clarion, Lower Kittanning, Middle Kittanning, Upper Kittanning, Lower Freeport and Upper Freeport. These coals do not have an unbroken continuity over the entire extent of the Allegheny formation but are found in restricted areas; the Brookville coal is found in the outer edge of the coal bearing rocks in Jefferson, Clearfield, Cambria, Center and Somerset counties particularly. The Clarion coal is found in almost the same area, though not always in the same localities. The Lower Kittanning coal is exposed in eleven counties in workable thickness, and is one of the most persistent of all the Allegheny coals. The Middle and Upper Kittanning coals are not found to contain much coal of present workable value; the Upper Kittanning carries some cannel. The Lower Freeport is a valuable member of the series and is well developed, especially in the Clearfield region. It is found in the counties of Center, Clearfield, Jefferson, Indiana and Cambria; in basins known as the Moshannon, Reynoldsville, Punxsutawney and the Barnesboro-Patton. It occurs in some places in this area as a rather low grade coal. The Upper Freeport coal while absent in some localities is yet found in a great part of this same area, often, however, a rather poor mining coal.

The Allegheny series shows a thickness of from 250 to 350 feet.

The Conemaugh formation extends for a thickness of about 600 feet above the preceeding one; it carries several, about six, coals which while not now worked extensively show considerable promise in Somerset county in the Berlin Basin.

The Monongahela formation varies in thickness from 200 feet in the western outcrop in Ohio to 380 feet on the Monongahela in Pennsylvania, and to over 400 feet in borings in West Virginia.. It car-

PLATE IV.

Fig. B.—Out crop of Pittsburg coal on Pike Run near Coal Centre, Washington County. Thickness of coal, 6 feet 11 inches. Photograph by F. Ehrenfeld, 1904.

PLATE IV.

Fig. A.—Surface topography of the Coal Measures at Indiana, Pa. Note the preponderence of rounded knobs due to erosion in horizontal strata; the higher beds of the Monongahela have been removed by eroision. Photograph by F. Ehrenfeld.

ries the great Pittsburgh coal bed which forms the base of the series. Above this Pittsburgh coal lie the Redstone, Sewickley, Uniontown, and Waynesburg coals; this last is often said to mark the boundary of the Permian though this line may be very much lower. These coals are in places of a good workable character, but the over shadowing importance of the Pittsburgh bed makes them of small value under present market conditions.

The Pittsburgh Coal Bed is all things considered the most famous bituminous coal bed in America; from it are obtained coals for almost every conceivable purpose for which a "soft" coal may be used; gases for illumination and furnace use, coke for blast furnace practice, high grade steam and power coal. In thickness it runs from 4 to 9 feet in Pennsylvania with an average of 7 feet; it runs about 5 feet in West Virginia to 22 feet in Maryland. In Pennsylvania it lies in almost unbroken area in the counties of Allegheny, Washington, Westmoreland, Somerset (in part), Fayette, Indiana (in part), and Greene; from this area it extends over into Ohio, West Virginia and Maryland. It also occurs in the "Broad-Top" field to the east.

Quality of the Coal. It is not to be expected that over so large an area the quality will remain uniformly good, nor that there will not be some areas in which the coal may be lacking. Over practically all of the above area the coal is good steam coal, much of it is gas coal; it is its availability for furnace coke which is of most importance. We quote the following from a report of the Topographic and Geologic Survey, Harrisburg, 1908, p. 229:

"Starting at the east outside of the area here considered, the Pittsburgh coal occupies a limited area in the Salisbury basin in Southeastern Somerset county. Here the coal has a fuel ratio of about 3.5. Analysis shows it to have about 70 per cent. of fixed carbon, 20 per cent. of volatile combustible matter, 8 per cent. of ash, .75 per cent. of sulphur and 1.25 per cent. of moisture. Coming westward a small basin of the Pittsburgh coal is found in Eastern Westmoreland county in the Ligonier Valley, at Ligonier. This is east of the Chestnut Ridge anticline. Here the coal shows a fuel ratio of a little under 3. Analyses will show about:

Fixed carbon,	62 per cent.
Volatile hydrocarbons,	23 per cent.
Ash,	12 per cent.
Sulphur, less than.	2 per cent.
Moisture (air dried) less than,	1 per cent.

Crossing the Chestnut Ridge anticline, the fuel ratio drops to about 2, the fixed carbon becoming about 60 per cent., the volatile hydrocarbons about 30, the ash 8, the sulphur 1 or less, the moisture (air dried) 1 or over. Here is the first large body of coal preserved and here is the great Connellsville-Uniontown coking district.

Continuing westward or northwestward, the Fayette anticline is crossed. This is the last of the sharply folded anticlines, and west of it the structure becomes gently and irregularly folded. Correspondingly, west of that anticline the coals have not lost so large a proportion of their volatile constituents. The fuel ratio in the Pittsburgh bed will there usually run under 2, and will average about 1.6. Thus most of the analyses will run from 50 to 60 per cent. of fixed carbon and from 30 to 37 per cent. of volatile matter. The ash runs rather high, usually from 10 to 12 per cent., and the sulphur usually between 1 and 2 per cent. Locally the ash runs down to 6 or 7 per cent. and the sulphur will run under 1 per cent.

Crossing the Monongahela river into Greene county, analyses indicate about the same grade of coal, some of the analyses giving a fuel ratio as high as 2 or even a little over, but averaging between 1.6 and 1.7. The percentage of ash is the same or lower and of sulphur about 1.

In Southeastern Washington county similar conditions hold. Analyses of the Ellsworth mines show from 53 to 59 per cent. of fixed carbon, and from 33.5 to 37 per cent. of volatile matter. The same analyses show from 4 to 8 per cent. of ash and from .73 to 1.61 per cent. of sulphur. Toward the northwest part of Washington county the Pittsburgh coal shows a marked increase in the percentage of sulphur, some of the analyses showing as high as 4 per cent. or over.

Waynesburg Coal. In the Uniontown syncline this coal has an average thickness of 3 feet 6 inches. West of this it has a much greater thickness but is usually split up with clay partings. Single benches range from 2 feet to 4 feet 6 inches at the best. Often by the removal of less than 1 foot of clay 5 to 6 feet of coal can be obtained. On account of this thickness—often over 10 feet—this coal makes a very prominent showing in the roads and elsewhere, but its high ash and sulphur and numerous clay partings render it a non-commercial proposition as long as the Pittsburgh bed remains. A sample from Greene county showed: 12.81 per cent. ash; 3.77 per cent. sulphur.

Waynesburg "A" Coal. While not as thick as the Washington coal, the Waynesburg "A" coal is probably the most valuable in the Dunkard formation. It shows a thickness of 3 to 4 feet 6 inches locally; with in general a thickness of under 2 feet. It will be of value only when the larger underlying beds are exhausted.

Washington Coal. The Washington coal is often thick but is usually so broken up with partings as to be nearly or quite worthless. It shows its best development in Washington county where it reaches a thickness of up to 7 feet, but of this the thickest bench is not more

Fig. 1.—Map showing area of the Pittsburg coal bed in Pennsylvania.

than 2 feet 9 inches. In Western Greene county it has a total thickness of 2 to 4 feet, but over most of Greene county is only 18 inches to 2 feet thick. Recent analysis shows:

Fixed carbon,	40.96 per cent.
Volatile hydrocarbons,	36.79 per cent.
Ash,	14.03 per cent.
Sulphur,	3.79 per cent.

At Ten-mile village is found the Ten-mile coal with a thickness of from 1 foot to 3 feet 2 inches."

COMPOSITION OF COAL.

Coal in composition is not "carbon" but is a mixture of hydrocarbons (chemical unions of carbon, hydrogen and oxygen) with variable amounts of nitrogen, sulphur, moisture and ash; the last three being usually spoken of as impurities. These elements are not present in a free or uncombined state but are united into a great many different chemical compounds which may be separated on distilling or burning into a series of hydrocarbons known as smoke, gas, tar. coke and so on, the final residue being known as ash.

The quality of coal depends in part on the amount and kind of the impurities present, the nature of the hydrocarbons present and also in part on the physical condition of the coal after mining.

The value of coal is of course dependent primarily on its quality; but the shape and position of the bed, cost of mining, nearness to a means of transportation, and proximity of other and more valuable coals all enter into the matter of value.

The Origin of Coal. It is generally agreed among geologists that coal has been formed in some manner from vegetable matter which has undergone very profound modification to make the various kinds of coal recognized; on the basis of this supposition a series of natural gradations has been distinguished from plant fibre and peat up to anthracite coal. These gradations are due to the variations in the character of the hydrocarbons present in these substances, and to the increase in percentage of carbon over that of hydrogen, oxygen, nitrogen, etc.; it is supposed that *graphite,* which is pure carbon, is the result of alteration of vegetable or organic matter. This is shown in the table following:

	Carbon.	Hydrogen.	Oxygen.	Nitrogen.	Sulphur.	Ash.	Water.
Plant fibre,	50.86	5.8	42.57	.77	....	....	....
Peat,	59.47	6.52	31.51	2.51	....	....	22.
Lignite,	52.66	5.22	27.15	.71	2.02	12.24	....
Sub-Bituminous,	58.41	5.06	28.99	1.09	.63	4.79	....
Bituminous,	82.70	4.77	9.39	1.62	.45	1.07	....
Semi-Anthracite,	83.14	4.58	4.65	1.02	.75	5.86	....
Anthracite,	90.45	2.43	2.45	....	....	4.67	....

As will be seen by the analyses there is a marked increase in carbon percentage as we pass from vegetable matter and peat up to anthracite. This is accompanied by a very noticeable decrease in the volatility of the coals so that anthracite coal is much less volatile than bituminous; that is it ignites less easily and burns with the separation of less smoke, and little or no coke residue. Coal burns by the oxidation of the carbon, the hydrogen not already united with oxygen, and to a much less important degree the oxidation of sulphur and other elements not already united with oxygen. "Coal ash" is the unburnable residue left after the complete oxidation of all the elements present in the coal. Various patent and secret nostrums have been set forth from time to time warranted to burn completely the coal ash; these are all based on a fallacious reasoning, inasmuch as coal ash is the mineral (stony) portion of coal, such as iron, lime, alumina, magnesia and so forth, which take up oxygen in burning and fuse together to form cinders or clinkers or else simply remain as ashes. It is no more possible to burn this material than it is to burn slag from a blast furnace.

The heating power of coal is then the result of oxidation or burning of these various elements present to their complete combustion and is usually called the "calorific value." This calorific value is expressed in two ways; as "calories" which means the amount of heat required to raise the temperature of one kilogram of water one degree centigrade; or it is expressed in British Thermal Units, B. t. u., being the amount of heat required to raise the temperature of one pound of water one degree Fahrenheit. Calorific values may be turned to British Thermal Units by multiplying the Calorific value by 1.8. Inasmuch as the chemical elements in coal are not always present in the same manner, or in the same amount, it is not possible to predict accurately what the Calorific value of a coal will be simply from the composition, that is percentages of carbon, hydrogen and so forth.

Coal Composition.

The chemical analyses of coal are frequently expressed in two ways as the proximate analysis and as the ultimate analysis. The first is based upon the fact that coals, especially the bituminous ones, are seen in burning to separate rather definitely into two sorts of hydro-carbon compounds, spoken of as volatile hydrocarbon (v. h. c.) and fixed carbon, (f. c.), together with moisture (H_2O), ash and sulphur.

The ultimate analysis is the expression of the total quantities of each actual element present as carbon, hydrogen, etc. From the analyses given above as elemental analyses of coal it will be seen that there is a marked increase in carbon over hydrogen as we ap-

proach anthracite coal; in general the higher the carbon content the more nearly the coal approaches anthracite, and finally graphite, and thus becomes of more difficult ignition. These chemical analyses are used as a basis for.

Classification of Coals.

"One of the most extensively discussed questions connected with the Pennsylvania anthracite and bituminous regions, and one about which the most unsatisfactory conclusions have been arrived at, has been the classification of the coals. The original division of our Pennsylvania coals into anthracite, semi-anthracite, semi-bituminous, and bituminous, was one founded largely upon their geographical distribution, although the supposed basis was the chemical composition of the coals. These names as they have been indelibly fixed upon coals produced from special sections or individual mines, will always, to some extent, be made use of by the coal trade; they have, however, no scientific value. An interesting discussion of this subject by Dr. Persifor Frazer, was published in *Report MM of the Second Geological Survey of Pennsylvania.* As a result, the following classification is suggested:

Classes of coals.	Ratio $\frac{C}{\text{Vol H.C.}}$:1.
Hard-dry anthracite,	from 99:1 to 12:1
Semi-anthracite,	from 12:1 to 8:1
Semi-bituminous,	from 8:1 to 5:1
Bituminous,	from 5:1 to 0:1

"In arranging the coals in this classification, and many others proposed, the accidental impurities, such as sulphur and earthy matter, are disregarded in the analysis, and the fuel constituents are alone considered. While this classification is probably the best which has been suggested for our Pennsylvania coals, and may be used provisionally as a scientific basis, the coals as at present graded by the coal trade could not be arranged under this or any other chemical classification; and I do not believe that we have sufficient data now at command to suggest a final arrangement which might be considered a scientific rating of the coals, and which would be accepted by the coal miners, venders, and consumers."

The above is quoted from Chas. A. Ashburner, Annual Report, Second Geological Survey of Penna., Harrisburg, 1886, page 301. Although written over 25 years ago, it is still true today that no satisfactory means of coal classification on the basis of chemical analysis has yet been devised. It has been suggested to use the total carbon content as a basis for such classification but there are obvious objections to this. Most coal analyses are now made both on an ultimate and a rational basis and on carefully selected samples. The details of this subject can not be considered here. From the above report

of Ashburner's the following table of coal analyses is taken to show the average composition of Pennsylvania anthracites. (op. cit. page 313).

The table is not of course complete nor in accord with more modern analytic practice. The whole matter of the composition of Pennsylvania coals is in an incomplete and unsatisfactory state and needs further detailed study. It is a matter of great importance that this study be taken up as soon as possible while there is opportunity of access to the coals through the numerous mines now open and before it is too late to be of practical value for the coals yet remaining unmined.

AVERAGE COMPOSITION OF PENNSYLVANIA ANTHRACITE.

No. of specimens.	Name of Coal Bed.	Name of Coal Field.	Chemical Analysis.*						Specific gravity.	Percentage of Constituents of Fuel.		
			Water.	Volatile matter.	Fixed carbon.	Sulphur.	Ash.	Total.		Fixed carbon.	Volatile combustible matter.	Fuel Ratio. C. / V. H.—C.
3	Wharton,	Eastern Middle,	3.713	3.080	86.404	.585	6.218	100	1.620	96.56	3.44	28.07
5	Mammoth,	Eastern Middle,	4.119	3.084	86.379	.496	5.922	100	1.617	96.55	3.45	27.99
2	Primrose,	Western Middle,	3.541	3.716	81.590	.499	10.654	100	1.654	95.64	4.36	21.93
5	Mammoth,	Western Middle,	3.163	3.717	81.143	.899	11.078	100	1.657	95.62	4.38	21.83
2	Primrose, ? F.,†	Southern,	3.008	4.125	87.982	.506	4.379	100	1.584	95.52	4.48	21.32
2	Buck Mountain,	Western Middle,	3.042	3.949	82.662	.462	9.885	100	1.667	95.44	4.56	20.93
1	Seven Foot,	Western Middle,	3.410	3.978	80.868	.512	11.232	100	1.651	95.31	4.69	20.32
7	Mammoth,	Southern,	3.087	4.275	83.813	.641	8.184	100	1.631	95.15	4.85	19.62
3	Mammoth,	Northern,	3.421	4.381	83.268	.727	8.203	100	1.575	95.00	5.00	19.00
	B. Coal Bed,‡,	Loyalsock,	1.295	8.100	83.344	1.031	6.230	100	....	91.14	8.86	10.29

*These analyses are arranged in the order of the percentage of fixed carbon in the fuel constituents.

†Called Red-Ash bed in the Panther Creek Basin.

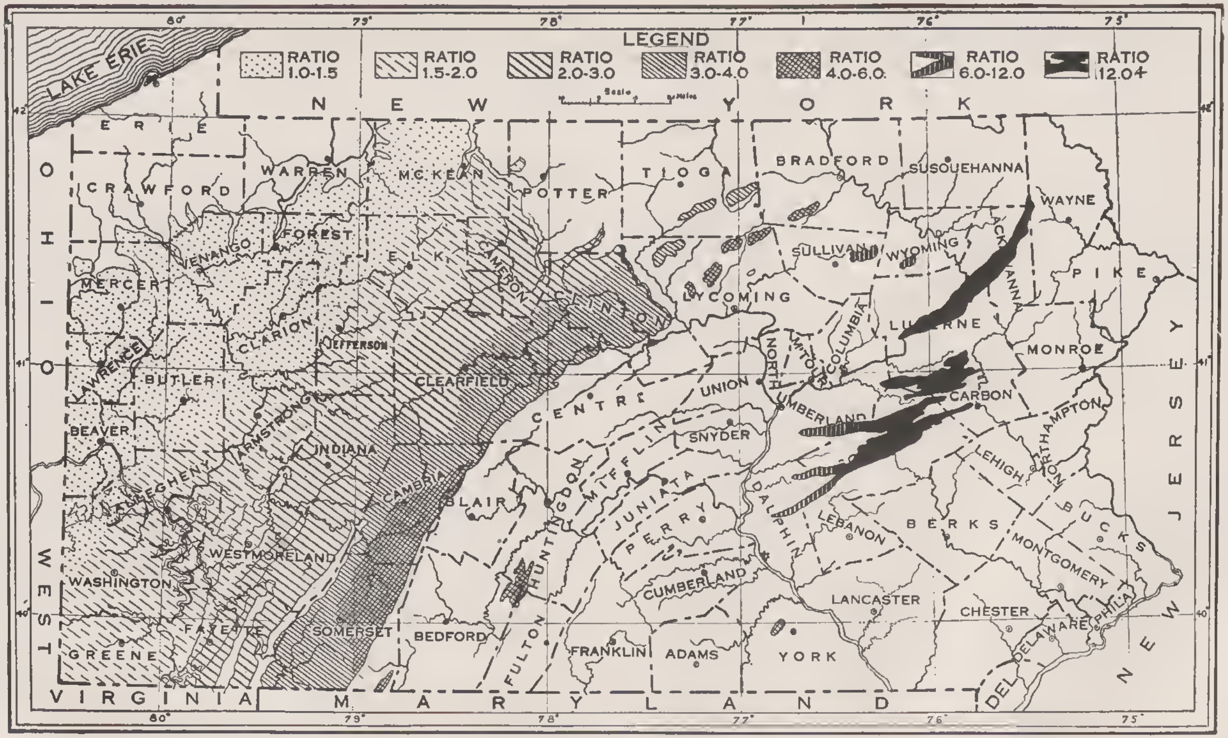
‡This coal, according to the classification referred to below, would be called a semi-anthracite, on account of its percentages of volatile matter and fixed carbon. The percentage of volatile matter is not as great, however, as that contained in many of the coals from the Shamokin and Lykens Valley districts, with which the Loyalsock coal favorably compares. The Shamokin and Lykens Valley coals are called anthracites by the trade, and on this basis the trade must consider Loyalsock or Bernice coal an anthracite.

4

"An attempt has been made on Plate V to indicate the distribution of the various grades of coal in Pennsylvania on the basis of the fuel ratios. Examination of the map shows the anthracite coal of Lackawanna, Luzerne, Carbon and Schuylkill counties to have a fuel ratio averaging over 20, the analyses showing from 80 to 88 per cent. of fixed carbon and from 3 to 4.5 per cent. of volatile matter. The western ends of those fields tend to grade into the semi-anthracite class. In Eastern Sullivan is the Bernice field of "soft anthracite" or semi-anthracite, with a fuel ratio of 6 to 10. This field contains coals that run over 80 per cent. of fixed carbon and under 9 per cent. of volatile matter, 83.4 of fixed carbon and 8.10 of volatile being a typical example. On the other hand most of the analyses on hand from the Bernice Basin show a fuel ratio of between 3.5 and 6. Then comes the Broad-Top field of Bedford and Huntingdon counties, in which the eastern edge has a higher fuel ratio than the western, and a strip along the Allegheny Front, where the rocks, if not more folded than farther west, have probably been subjected to much greater stress. The rocks west of the Allegheny Front seem to have served as a buttress against which the rocks to the east were folded, and it is natural to suppose that the face of this buttress should suffer more severely than the rocks farther back. The folding is not always more noticeably pronounced close behind the front, but in Clearfield county at least mining has brought out the fact of extensive thrust faulting, and all of the coals near the face tend to be minutely dissected with fracture planes, making the coals tender and soft, so that there is found from Bradford county a strip running through Lycoming, Southeast Clearfield, Eastern Cambria and Somerset counties, where the coals have a fuel ratio of from 4 to 5. At South Fork in Cambria county the fuel ratio runs close to or quite to 6. West of that through the same counties, and extending over into Tioga and Clinton, the coals show fuel ratios of from 3 to 4. Coming between 2 and 3 will be found the coals of the Allegheny or Lower Coal Measures in Blair, Clinton, Indiana, Westmoreland and Fayette counties, and part of the Pittsburgh coal, though only that portion in the basin immediately west of Chestnut Ridge, where it has been involved in relatively close folding. It is noticeable, for example, in Indiana county that while the Pittsburgh coal in that county will run about 1.6, the Allegheny coals will run from 2.5 to 3. The Connellsville coking coal of Westmoreland and Fayette counties will as a rule run about 2, sometimes reaching as high as 2.5. As a rule, however, the Pittsburgh coal will run between 1.5 and 2[1].

Analyses of the Pittsburgh coal from the Connellsville district. The coal from this territory has long been famed as the source of what is probably the highest grade of coke made in America and it is not

[1]Top. and Geol. Survey Commission, 1906-08, p. 223.



MAP OF PENNSYLVANIA, SHOWING DISTRIBUTION OF COALS BY FUEL RATIOS.

PLATE V.

Map of the Elders Ridge coal field, Pennsylvania.

PLATE VI.

necessary here to more than refer to it briefly by giving a few analyses.

Analysis of Pittsburg (Connellsville) coal from Broadford.[1]

Water,	1.260
Volatile matter,	30.107
Fixed carbon,	59.616
Sulphur,	00.784
Ash,	8.233
Total,	100.000

Average analysis from a number of determinations made in 1893. H. C. Frick Coke Company.[2]

Water,	1.130
Volatile matter,	29.812
Fixed carbon,	60.420
Sulphur,	0.689
Ash,	7.949
Total,	100.000

Average of Connellsville coke by analysis.

Water,	0.070
Volatile matter,	0.880
Fixed carbon,	89.509
Sulphur,	0.711
Ash,	8.830
Total,	100.000

Analysis by H. C. Frick Coke Company.

Average composition of Connellsville Coke (McCreath).

Water,	00.300
Volatile matter,	00.460
Fixed Carbon,	89.576
Sulphur,	00.821
Ash,	9.113
Phosphorous,	00.014
Total,	100.284

Both the above tables are copied from U. S. Geol. Survey, Folio 94, page 17.

The accompanying map and analyses of the Pittsburgh coal from the Elders Ridge district are taken from Bulletin 225 U. S. Geological Survey, Washington, 1903. The analyses of this coal and the coke made from it show considerable variation in character from those of the Fayette (Connellsville) district.

Analyses of Pittsburg Coal from Elders Ridge Field.

Locality.	Fixed carbon.	Volatile matter.	Moisture.	Ash.	Sulphur.	Fuel ratio.	Coke.	Authority.
	%	%	%	%	%	%	%	
Avonmore,	56.432	35.040	0.720	6.810	0.988	1.61	64.23	L. W. Hicks.
Arnold 1,	55.17	32.99	.51	10.33	.98	1.67	66.48	C. B. Dudley.
Arnold 2,	56.47	30.02	.63	11.83	1.02	1.88	69.32	Wuth & Stafford.
Iselin,	56.34	31.48	1.76	10.42	1.25	1.79	68.01	George Steiger.
Ashbaugh,	53.639	37.555	1.110	6.260	1.436	1.43	61.335	A. S. McCreath.
Ewing,	50.230	36.900	.800	9.030	3.040	1.36	62.30	A. S. McCreath.
Evans 1,	50.850	36.940	1.040	9.705	1.465	1.38	62.02	A. S. McCreath.
Evans 2,	53.788	31.995	1.460	11.760	.997	1.68	66.545	A. S. McCreath.
Holsten,	56.25	33.41	1.61	8.73	1.87	1.68	66.85	E. C. Sullivan.

[1]Analysis by A. S. McCreath.
[2]U. S. Geol. Survey, Folio 94, page 13, 1903.

Comparative Analyses of Coke.

	Elders Ridge.	Connellsville.
	%	%
Fixed carbon,	90.532	89.509
Voltatile hydrocarbons,	....	.880
Moisture,	....	.070
Ash,	7.411	8.830
Sulphur,	2.057	.711
	100.000	100.000

Two analyses of coke made from Pittsburgh coal are given above. The first was made by A. S. McCreath from coke made in the laboratory of the Second Geological Survey of Pennsylvania by coking coal in a platinum crucible. The coal was from the Saltsburg Coal Company mine in the southern block of the Elders Ridge field. The second is the average of a number of analyses of typical Connellsville coke made by the H. C. Frick Coke Company. The amount of sulphur in the Elders Ridge coke is too high for a first-class product, but this might be remedied by washing the coal to get rid of part of the sulphur.

LOWER FREEPORT COAL.

The following analyses taken from Bulletin 225, U. S. Geological Survey, page 302, show the character of the *Lower Freeport* coal from the Barnesboro district:

"*Quality of the Coal.*—The Lower Freeport coal carries a large amount of sulphur in the form of "knife blades" and iron nodules in many parts of the region. Impurities seem to decrease west of Barnesboro and the coal becomes suitable for coking. The coal of the Greenwich mines near Garmans Mills is shipped to the Maryland Steel Company at Sparrows Point, Md., where it is coked in by-product ovens with excellent results. Three reported analyses of the coal from these mines show the following composition:

Analyses of the Lower Freeport Coal from near Garman's Mills, Pa.

	I.	II.	III.
	Per Cent.	Per Cent.	Per Cent.
Moisture,	(a)	(a)	(a)
Volatile combustible matter,	25.34	26.48	26.86
Fixed carbon,	65.81	65.84	67.88
Ash,	8.85	7.68	5.26
Sulphur,	.80	.71	.64
Phosphorous,	.008	.005	.003

*a*Not determined.

Following is a comparison of the average of 10 determinations of coal from the Greenwich mines and an average analysis of the Connellsville coal furnished by the H. C. Frick Coke Company.

Comparative Analyses of Connellsville and Lower Freeport Coals.

	Connellsville coal, H. C. Frick Coke Co.	Lower Freeport coal, Greenwich mines.
	Per Cent.	Per Cent.
Moisture,	1.130	(a)
Volatile combustible matter,	29.812	25.099
Fixed carbon,	60.420	66.300
Ash,	7.949	7.757
Sulphur,	.689	.840
Phosphorus,	(a)	.004
	100.000	100.000

a Not determined.

No moisture determinations were made of the Lower Freeport coal in these analyses, but a number of others show the moisture to be much less than 1 per cent."

COALS OF THE ALLEGHENY FORMATION.

The following table of analyses of coals from the Kittanning and Rural Valley quadrangles is taken from U. S. Geol. Survey, Bulletin 279; it shows the comparative merits of some of the Allegheny coals from various localities.

ANALYSES OF COALS IN THE KITTANNING AND

No.	Name of Seam.	Locality.	Owner.	Analyst.
1	Clarion, ...	West Winfield, ...	A. G. Morris, ...	E. C. Sullivan, U. S. G. S.*a*
2	Lower Kittanning,	Mahoning, ...	Mahoning Coal Co., ..	A. S. McCreath (H5, p. 232).
3	......do	Rogers farm, west of Buffalo Mills, near county line.	....	A. S. McCreath (H5, p. 287).
4	......do	Kittanning, ...	Kittanning Clay Mfg. Co.	Geo. Steiger, U. S. G. S.*a*
5	......do	Mouth of Cowanshannock Creek.	....	......do.*a* ....
6	......do	Craigsville, ...	Mr. Bowser, ...	......do.*a* ....
7	......do	¾ mile east of Greendale.	Rhea farm, ...	A. S. McCreath, ...
8	Upper Kittanning,	Bostonia, south of New Bethlehem.	Redbank Mining Co., cannel bench, analysis No. 1.	A. S. McCreath (H., p. 240).
9	......do	......do	Redbank Mining Co., cannel bench, analysis No. 2.	......do ....
10	......do	......do	Redbank Mining Co., .. bituminous bench.	......do ....
11	......do	Cathcart Run, ...	Brooks bank, ...	A. S. McCreath (H5, p. 180).
12	......do	Little Mudlick Creek,	Thompson bank, upper bench, bituminous.	......do ....
13	......do	......do	Thompson bank, middle bench, cannel.	......do ....
14	......do	......do	Thompson bank, lower bench, bituminous.	......do ....
15	......do	Pine Furnace, ...	....	A. S. McCreath (H5, p. 123).
16	......do	Yatesboro, ...	B. Schreckeugost, ...	A. S. McCreath (H5, p. 94).
17	Lower Freeport, ..	Cowansville, ...	Cowansville Mining Co.	W. F. Schaller, U. S. G. S.*a*
18	......do	Mahoning Furnace, ...	....	A. S. McCreath (H5, p. 161).
19	......do	Bostonia, ...	Redbank Coal Co., ...	A. S. McCreath (H5, p. 192).
20	Upper Freeport, ..	Near Freeport, off quadrangle.	....	A. S. McCreath (H5, p. 262).
21	......do	1¼ miles southwest of North Buffalo post-office.	Bruner bank, ...	Geo. Steiger, U. S. G. S.*a*
22	......do	1 mile east of Ewing,	Galbreath bank, ...	......do ....
23	......do	Stewardson Furnace (Dee).	....	A. S. McCreath (H5, p. 171).
24	......do	Bostonia, ...	Redbank Coal Co., ...	A. S. McCreath (H5, p. 193).
25	......do	Mahoning Furnace, ...	Colwells mine, ...	A. S. McCreath (H5, p. 160).
26	......do	Mosgrove, ...	Pittsburgh Plate Glass Co.	....
27	......do	Yatesboro, ...	Patterson mine, ...	A. S. McCreath (H5, p. 91).
28	......do	Blanco, ...	Beers bank, ...	A. S. McCreath (H5, p. 92).

*a*Collected by J. S. Burrows.

Note.—H and H5 in "Analyst" column refer to reports of the Second Geological Survey of Pennsylvania.

Fixed carbon.	Volatile combustible.	Moisture.	Ash.	Sulphur.	Phosphorus.	Total.	Color of ash.	Coke (per cent).	Character of coke.	Fuel ratio.
50.83	36.19	2.20	10.78	b3.35	....	100.	Slightly red.	....	Swollen, porous.	1:1.44
49.686	42.550	1.180	4.585	1.999	.0061	100.0061	Pinkish gray.	56.270	....	1:1.17
48.747	42.720	1.160	5.065	2.313	....	100.00	Reddish gray.	56.120	....	1:1.14
53.59	35.09	1.61	9.71	b4.62	....	100.00	....	....	....	1:1.52
49.19	32.93	3.19	14.69	b7.32	....	100.00	....	....	....	1:1.49
52.97	37.06	1.89	8.08	b4.41	....	100.00	....	....	....	1:1.42
52.032	38.205	.906	5.140	3.663	....	100.00	Reddish gray.	60.835	....	1:1.36
46.194	30.490	.510	22.230	.576	....	100.00	....	....	..Poor,..	1:1.51
49.815	31.680	.730	17.320	.435	....	100.980	....	....	do	1:1.54
52.716	39.120	1.650	3.880	2.634	....	100.00	Brown, ..	59.23	....	1:1.34
52.306	32.665	.640	13.345	1.044	....	100.00	Gray, ...	66.695	....	1:1.60
52.575	37.930	1.120	6.705	1.388	....	100.00	Reddish gray.	60.850	....	1:1.39
53.132	37.830	1.610	6.750	.678	....	100.00	Gray, ...	60.560	....	1:1.40
54.482	34.465	.810	9.655	.588	....	100.00	do	64.725	....	1:1.58
58.301	34.185	1.820	4.705	.989	....	100.00	Cream, ..	63.995	....	1:1.70
53.224	34.270	.910	9.285	2.211	....	100.90	Gray, ...	....	....	1:1.55
53.34	31.73	2.97	11.96	b3.51	....	100.00	....	....	Good, ...	1:1.62
50.265	37.110	1.070	8.330	3.225	.0092	100.0992	Pinkish gray.	61.820	....	1:1.35
53.960	35.940	1.690	5.040	3.380	....	100.00	Gray, ...	62.370	....	1:1.50
50.206	39.835	1.430	5.710	2.819	....	100.00	Cream, ..	58.735	....	1:1.26
51.37	29.00	2.17	17.46	b2.58	....	100.00	....	....	....	1:1.77
49.78	31.65	2.72	15.85	b4.06	....	100.00	....	....	....	1:1.57
55.545	35.520	1.470	6.630	.835	.0684	100.00	Yellowish gray.	63.010	....	1:1.56
53.661	35.940	1.840	6.820	1.739	....	100.00	Gray, ...	62.220	....	1:1.49
54.996	34.810	1.450	7.690	1.054	....	100.00	do	63.740	Tender, .	1:1.58
51.18	34.22	2.30	10.70	1.65	....	100.00	....	....	....	1:1.48
53.569	36.995	1.020	5.775	2.461	....	99.820	Cream, ..	61.981	....	1:1.45
57.179	37.860	1.140	2.790	1.031	....	100.00	do	61.000	....	1:1.51

*b*Sulphur separately determined.

PENNSYLVANIA COKE DISTRICTS.

No. 1. Connellsville: The County of Fayette and the southern half of Westmoreland.

Pittsburgh: Vicinity of Pittsburgh, the coke being made from coal brought down the Monogahela river.

No. 2. Reynolds and Walton: All the ovens on the Rochester and Pittsburgh Railroad, those on the Low Grade Division of the Allegheny Valley Railway, and the mines on the New York, Lake Erie and Western Railway.

No. 3. Upper Connellsville: The region around and north of Latrobe, the coal being somewhat different from the deposit farther south.

No. 4. Allegheny Mountain: Ovens along the line of the Pennsylvania Railroad from Galitzin to beyond Altoona, and those in Somerset County. This includes also the coke ovens near Johnstown.

No. 5. Clearfield—Center: The two counties of Clearfield and Centre.

No. 6. Greensburg: Near the town of Greensburg, in the central part of Westmoreland County.

No. 7. Broad Top: The Broad Top coal field in Bedford and Huntingdon Counties.

No. 8. Lower Connellsville: A new district, first appearing in the U. S. reports in 1900. Known also as the Klondike district, a southwest extension of the Connellsville Basin.

No. 9. Irwin: The neighborhood of the town of Irwin on the Youghiogheny river, in the western part of Westmoreland county.

The Beaver, Allegheny Valley and Blossburg districts, formerly recognized, are no longer of importance.*

COPPER.

Copper in quite a variety of mineral forms has been found in the State, all of them in the eastern portion. Some of these localities are of no importance except of interest to the professional mineralogist; other localities have been much exploited and in fact at times have gone through the phases of "booms," and in the South Mountain, in the Adams-Franklin district, there are regularly organized companies with a number of mines and smelters.

The mineral forms in which copper occurs are numerous. Those which have been found to be the chief producing types are the sulphide ores, the carbonate ores to a lesser degree, and at Lake Superior the "native copper" or free metal.

Representatives of all these are in this State.

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*"Iron and Steel," H. H. Campbell, New York, 1903.

Ores of Copper.

Chalcopyrite Cu FeS_2. Copper 34.5 per cent., copper-iron sulphide. Brass-yellow color.

Chalcocite Cu_2S. Copper 79.8 per cent.; copper sulphide. Black color.

Bornite. Cu_3 FeS_3. Copper 55.5 per cent.; copper-iron sulphide. Peacock color.

Cuprite. Cu_2O. Copper 88.8 per cent.; copper oxide. Red in color.

Malachite, Azurite. Copper carbonates with water. Copper 61.62 per cent. Malachite is green; Azurite is blue in color.

While there are in other states, copper camps producing valuable yields from these two minerals, (the carbonates) the ores which are regarded as the chief and most likely to be of permanent value are the sulphide ones. Metallic copper is a valuable deposit at Lake Superior, but in this State, like cuprite, is local only and not of much abundance.

The chief copper minerals are Chalcopyrite and Chalcocite. Copper has been found in the State at the Ecton Mine, the Jones Mine in Montgomery and Berks counties; at French creek, Chester county; at the Cornwall mines, Lebanon county; the Gap mine, Lancaster county (see under nickel); at all of these places as *Chalcopyrite.*

This mineral has also been found in small or minute quantities in the gneiss rocks from Frankford and the Wissahickon and from the Lafayette soapstone quarries. The Chalcopyrite from the old Wheatley mine gave copper 32.85 per cent. In the Triassic "red rocks" of Montgomery, Bucks, York, Lancaster and other counties small quantities have been reported at various other places.

Bornite is much less common and is found at few places in this State. These are in several places in York and Adams counties, as at Dillsburg and Gettysburg in the Trias; at Lafayette, McKinney's quarry, Germantown, and elsewhere in minute amount. It has been found in the Adams-Franklin district. In Lycoming, Sullivan and other counties it is reported, (Genth Rep. B.) as being in the Devonian rocks.

Cuprite and Native Copper have been found and are still found in the iron ore at Cornwall. Some very fine specimens of each have been taken from these mines, these are likely to be found as ruby red or brick-dust red forms along with the other copper minerals. Native Copper is "copper red" in color. Malachite and Azurite are common wherever other copper minerals occur, and are found often as stains on rocks. Very fine specimens of the two carbonates, Malachite (green) and Azurite (blue), have been found in the past at the old Jones mine, Montgomery county, and at Cornwall. These specimens have in many cases gone to enrich the numerous collections, public and private, in Philadelphia and vicinity.

The South Mountain copper occurrences in Adams and Franklin counties have excited great interest in this State and are at present practically the only places where copper is being systematically exploited in the State. The mines are situated near Charmian and Fairfield in Pennsylvania and the same copper rocks outcrop in Carrol county, Maryland. Geologically the copper bearing rocks are found in what is known as the "Pre-Cambrian." These are formations of a very ancient origin and are very like the formations at Lake Superior. In Pennsylvania they are rocks of an eruptive (volcanic) character, both acid (siliceous) and basic. These volcanic rocks have been in the lapse of great time very much changed and are not like ordinary lava. They are generally known as "porphyry" or rhyolite for the acid ones, and "green stone" for the basic ones. The copper occurs chiefly with the basic or green stone rocks and generally at or near the contact of these with the acid ones. The ore is usually small grains or lumps, wires, flat scaly pieces or rough pieces of native copper; red oxide (cuprite) also is found, as are malachite and azurite. These last two often occur as stains on or in the rocks.

Epidote a pistachio green or olive green lime silicate mineral. The green color in this mineral is due to *iron* not copper.

The absence of large amounts of sulphide ore in this region is noteworthy. There are some ten mines which have been worked in the region; the one most active at present is about a mile north of Charmian. Several bore holes reported to be 300-400 feet deep have been made. Anaylses of samples of ores are not available, nor of the products from the smelters. So far as can be seen by the practical results the district has not yet established itself as a copper producer. The field has been prospected and opened for almost seventy-five years, though not always with modern methods, and the persistent absence of large veins of sulphides is not an encouraging sign, though perhaps further borings will show their presence. It is very much to be desired that the energy and money already spent be followed by the discovery of permanently valuable deposits of copper. At present it does not seem possible to pass a final opinion as to the future possibilities.

A word or two of caution may perhaps be added. There are many places where the green and blue and red stains of copper minerals seem to show large amounts of copper present. These are very deceptive as a small quantity of stain may cover much rock and represent so small a percentage of metal as to be valueless.

Secondly no one should invest money in any gold, silver, copper or lead mine in this State unless he can afford to lose it. While there are always possibilities of experts being mistaken it must be said that the present indications are against the discovery of really large deposits of these metals in Pennsylvania.

CORUNDUM.

This mineral, known also as ruby, sapphire, and in an impure form as emery, consists when in chemically pure state of oxide of aluminum, Al_2O_3; percentage of aluminum, 52.9. It often has iron, chromium and other impurities present. Corundum is found chiefly in the serpentine belt that comes diagonally across Maryland through the counties of Lancaster, York, Chester, Delaware, Montgomery, Lehigh, Northampton, Berks, and Bucks in Pennsylvania. Corundum is found associated with it in many places, especially in Chester and Delaware counties, and, a few years ago, was mined to some extent in Chester county. Considerable prospecting has been done in Pennsylvania, but the mines are now abandoned.

Corundum has probably been found more abundantly near Unionville, in Newlin Township, Chester county than elsewhere. It is found here in a mass of serpentine rock, with an average width of about 800 feet and a length of 1 mile. A number of tons of corundum have been obtained from this mine, but during the last ten years little or no work has been carried on. The gem varieties, ruby and sapphire, are not found in good quality in this State though interesting specimens are sometimes discovered. The chief uses of corundum are for abrasive purposes, as wheels, powders, "flours," stones, etc. It it also used sometimes as an ore of aluminum but when in good pure condition commands a higher market price as an abrasive as it is next to the diamond the hardest known natural substance. *"Carborundum"* a carbide of silicon, a manufactured product, is often popularly confused with corundum. *"Alumdum"* is a somewhat similar substance, and is stated by its manufacturers to be an artificial corundum made in the electric furnace.

According to Mr. W. W. Jeffries, as quoted by Mr. Joseph Willcox, Messrs. John and Joel Bailey claim to have discovered corundum in the serpentine region of Chester county, Pa., about 1822 to 1825. Dr. Thomas Seal collected specimens at Unionville about 1832; Mr. Jeffries himself saw large lumps in the fields there in 1837 or 1838;* and a ton of surface fragments and bowlders was collected about 1839 and shipped to Liverpool. But the search for the source of this material was unsuccessful till 1875, when a large lenticular mass was found in place. This consisted chiefly of corundum and margarite and carried some fine specimens of diaspore.†

The chief localities are as follows:

Unionville.—In a large mass of serpentine rocks, one mile northeast of this village, corundum has been found. It occurs here also in Albite feldspar.

Villagegreen.—Large crystals of corundum of a brownish color are found near this village, in Aston township, Delaware county.

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*Second Geol. Survey Pennsylvania, C. 1883, pp. 346-351.
†Second Geol. Survey Pennsylvania, B. 1875, pp. 31-33.

West Chester.—Corundum has been found in a serpentine of this township.

Blackhorse.—Slender grayish crystals of corundum have been found at this place, which is near Media, Delaware county. This has been found inclosed by feldspar. The crystals may be found loose in the soil.

Fremont.—Near this place, in West Nottingham township, Chester county, corundum crystals have been found, surrounded by feldspar.

Mineral Hill.—Corundum crystals have been found at this place, which is near Media, in Middletown township, Delaware county. They were surrounded by feldspar similar to that at Blackhorse.

Newlin.—See under Unionville.

Shimerville.—At this place, in Lehigh county, corundum crystals up to 8 inches in length and 4½ inches in diameter have been found loose in the soil. The Shimerville locality was originally discovered by Dr. Edgar F. Smith, of the University of Pennsylvania, Philadelphia. Several tons of corundum crystals were taken out from this locality. The locality is reported as being reopened. The corundum is in a feldspar.

In the collections of the Academy of Natural Sciences, Philadelphia; the University of Pennsylvania, which has now the well known Cardeza collection, and in the Jeffries collection now at the Carnegie Museum, Pittsburgh, are many specimens of Pennsylvania corundums.

Corundum as stated above occurs in practically the same general field as the serpentine area and, in many places, near the localities given above, crystals may be still found. At present it is not considerably exploited in this State.

The crystals of corundum are six sided and generally flat at ends. When the crystals are small they are usually well developed, with smooth faces and sharp edges; the larger crystals are rough, striated, often rounded, and taper slightly toward the end, like a barrel, so that they are sometimes called "barrel corundum." At Shimerville were found barrel crystals more than 6 inches in diameter. They are most often in the Pennsylvania localities of a gray color. In some places the sapphire (blue) or ruby (red) colors are found but not in gem quality, except in small pieces.

CYANITE.

This rather pretty mineral, sometime used for gem purposes, has been found in the State in fine specimens. It is a silicate of alumina with a variety of colors, from greys running up to deep blue. Very beautiful specimens, in large flat pieces and in radiating masses, have been found in the decomposed mica rocks near Darby, at Leiper-

ville, Black Horse and other places in Delaware county; near Philadelphia on the Wissahickon; at the Poorhouse quarry and other places in Chester county, and in Bucks county near Bustleton.

Aside from gem purposes cyanite has no commercial importance.

DOLOMITE. (See Limestone, also Magnesian Minerals).

EPIDOTE.

This is a pistachio or olive-green clored mineral found in association with some of the rocks of the Triassic formation and also not infrequently in the rocks of the South Mountain; it occurs along with native copper in Adams county and is popularly believed to be a certain indicator of the presence of this metal. This is however an error as epidote has no copper in its composition, and it occurs in many places far away from any copper minerals.

It is a silicate of alumina with lime iron and, rarely, manganese; *piedmontite* is a rather brownish manganese variety found in the eruptive rocks of Adams county.

Thulite is a rose-pink colored variety of *zoisite,* a mineral very similar to epidote; thulite occurs in beautiful specimens along with feldspar at Leiperville and in other similar rocks near Chester. Epidote and zoisite are often found along with allanite, magnetite, zircon, and copper; in general with minerals resulting from the alteration of rock or mineral masses. Epidote is found in many localities in Pennsylvania. In the regions of the Trias it is sometimes found in rounded lumps or nodules, often brown on the surface but green on the inside.

FELDSPAR "SPAR."

The important group of minerals known as Feldspar includes natural silicate compounds of alumina with potash, soda, lime, or rarely barium. The feldspars are commonly divided into two groups known as *Orthoclase and Plagioclase.* These are named primarily according to the shape of cleavage or breakage pieces. The Orthoclase is always in squarish or oblong pieces having angles of 90°, or square. The ends are usually rough. The Plagioclase feldspars do not have this square cleavage so completely developed as the Orthoclase and have often fine parallel lines, like rulings, upon the cleavage faces; they are soda, lime, silicates.

The names and compositions of the feldspars are given in the following table:

Names and Composition of Feldspars.

Name.	SiO_2.	Al_2O_3.	CaO.	K_2O.	Na_2O.
Orthoclase,	64.7	18.4	....	16.9	....
Albite,	68.7	19.5	....	....	11.8
Oligoclase,	65.7	21.5	2.4	....	10.4
Andesite,	57.3	27.1	8.9	....	6.6
Labradorite,	53.0	30.1	12.3	....	4.6
Anorthite,	43.2	36.7	20.1	....	....

As will be seen from the above ideal compositions the feldspars make a series of chemical compounds known as silicates, in which there is a gradual progression from potash (K_2O) down through soda (Na_2O) to lime (CaO). The series from Albite to Anorthite are known as the "soda-lime" feldspars, they are usually called "the plagioclases" among mineralogists. The specific gravity ranges from 2.57 for Othoclase to 2.76 for Auorthite. The composition of actual samples of feldspar as found shows nearly always the presence of potash and soda together and pure specimens are not common. Iron also is generally present in small amounts causing a pinkish or even reddish color.

Microcline known also as "Amazon stone," when green, is a potash feldspar akin to Orthoclase and has generally a green color somewhat like jade. It is much used for gem purposes under the name "amazonite."

Moon stone is a form of Albite which has a beautiful blue color when polished or broken across the cleavage.

Sun stone is either Oligoclase or Albite, also used as a gem stone. It possesses a reddish color when held in certain positions due to the inclusion of small pieces of iron ore or scales of mica.

Analyses of Pennsylvania Varieties of Feldspar.

Orthoclase.	SiO_2.	Al_2O_3.	CaO.	K_2O.	Na_2O	Fe_2O_3.
(a) Brandywine Summit,	65.76	18.94	....	12.68	1.80	....
(b) French Creek,	62.68	20.90	0.15	15.99	....	0.23
(c) Glen Hall,	70.36	19.34	1.56	3.00	4.68	....
(d) Mineral Hill,	64.90	20.92	....	10.95	3.95	0.28

(a) T. C. Hopkins, Mineral Industry, Vol. 7, p. 263.
(b) Dana, System of Mineralogy, p. 319. Genth Analyst.
(d) " " " " p. 323.

Albite.						
Mineral Hill,	66.34	20.72	1.85	0.98	9.44	....
Unionville,	66.65	20.79	1.47	1.36	8.86	....

T. C. Hopkins, op. cited.

Oligoclase.	SiO_2.	Al_2O_3.	K_2O.	Na_2O.	CaO.
Wilmington, (Del.)	64.75	23.56	1.11	9.04	2.84

Uses of Feldspar.

Feldspar is used very extensively in the manufacture of china and porcelain, where it is used to influence the character of the "mix" as to fusion, body, etc. High grade kaolins contain some feldspar in places. It is used also as a source of alumina and potash, though for this last it is not yet a very satisfactory commercial source. Feldspar is also used as a binder in making emery wheels, in the manufacture of certain sorts of glasses and enamels; as a polishing or scouring medium, owing to its less gritty character than silica, this is especially so in some scouring soaps.

Occurrence in Pennsylvania.

The rocks which carry feldspar in quantities large enough to be of any commercial value, or even in large enough quantity to be worked for any purpose, are all in the eastern part of the State. Feldspar has been found as far west as Lancaster and York counties and probably will be found in the very ancient rocks of the South Mountain, in the Adams-Franklin district, though whether in valuable workable amount is doubtful. At Bald Friars on the Susquehanna it occurs with black tourmaline. It has been found also in Lehigh county and in Berks, Bucks and other places in the South Mountains. The chief localities and those where it has been commercially exploited are in Delaware and Chester counties. The chief occurrences are in rocks of a general granitic type, that is those made up essentially of quartz, mica and feldspar, in these rocks, as at the quarries near Chester, feldspar occurs in veins in the gniessic or granitic rocks, along with much quartz and some mica. Feldspar occurs also in connection with serpentine and in such places is apt to be associated with corundum, as at Mineral Hill in Delaware county. Trap rocks contain the plagioclase feldspars as an essential part of their constitution, but usually in very small crystals.

To mention here all the localities where feldspar is found in Pennsylvania is not practicable; it has been mined in the past and is still to be found along a line from the Leiperville quarries, near Chester, to Upland, Avondale, Media and in general along Crum Creek, (these localities are in Delaware county); in Chester county at many localities as at Unionville, Pennsbury, West Chester, and Brinton's quarry; it occurs in a more or less connected line from West Philadelphia to Frankford, some places in good sized crystals; in Germantown, Chestnut Hill, and from there to the Schuylkill are other localities.

At Mineral Hill, Delaware county occur a great variety of feldspars: *moonstone, sunstone*, and beautiful microcline of various shades of green; this locality has yielded rich material for the numerous collections around Philadelphia. At Chester have been found very large

crystals, some two feet in length and 12 to 18 inches thick are in the collections of the University of Pennsylvania, Philadelphia, where there are many hundreds of feldspar crystals from the State.

Feldspar is now (1912) mined at the following places, Avondale, Chatham, New Garden, Toughenamon, West Cain (potash feldspar), and near the Maryland line (soda feldspar), these are in Chester county; in Delaware county at Elam; other localities were formerly worked in Montgomery county.

FLAGSTONE. (See silica, sandstone.)

FLUORITE: Calcium fluoride, Fluorspar.

This mineral, while not a commercial product in this State, has been found at a number of localities, mostly in the limestones of the Great Valley or in some of the iron or other mines.

"It occurs associated with small rhombohedra of calcite in veins of massive calcite in the blue limestone, (Cambrian, at York). It is crystalline in structure, though no perfect crystals have been observed. It varies in color from light to dark purple. Sp. gr.=3.13. Analysis showed the usual composition, the Fl being determined by difference.

Ca=48.76%
Fl=51.24%

100.00%"*

It is reported also, probably in the same limestone, from Pine Grove, Cumberland county; from S. Plum's farm in Franklin county; in Berks county at De Turks, Exeter township. In Chester county at the old Edwards quary, Newlin township, in limestone. In the gneissic rocks at Frankford, and Falls of Schuylkill, Philadelphia; at Ironton, Lehigh county, and at the Wheatley mine, Phoenixville, from where a sample has been analyzed by J. L. Smith. (Report B. p. 29.)

Fluorine,	48.29
Calcium,	50.81
Phosphate of lime,	trace
Sp. gravity,	3.15

It is found also at Cornwall, Lebanon county, and at Delaware Water Gap.

Fluorspar is found mostly in limestone, where it occurs in squarish crystals or in lump form showing a great variety of color; blue to purples (like amethyst quartz but much softer), green, red, white, yellow or almost black. It is sometimes a common mineral with lead

*C. H. Ehrenfeld. The Journal of Analytical Chemistry. Vol. IV, part 3, July, 1890.

and zinc ores. It is easily scratched by a steel point. The chief uses are in foundry workings of iron and in making spiegeleisen; as a source of hydrofluoric acid for etching glass; as a useful ingredient in enamels, glazes, artificial gems and as electrodes. It is not found in this State in large quantity.

GALENITE. (See lead and zinc.)

GANISTER. (See silica.)

GARNET.

Garnet like "mica" and "feldspar" is a name given to a group of minerals of which there are eight or ten varieties.

The composition of garnet shows silicate minerals, with lime-aluminum; magnesium-aluminum; iron or manganese aluminum; and even chromium and titanium.

Character. Garnets are usually found in many sided crystals, are above steel and quartz in hardness and occur in greatest abundance in mica schist rock and in veins in granite gneiss and mica schists, along with mica, feldspar quartz and sometimes beryl.

The following are the chief species.

Grossularite—lime-aluminum garnet, $Ca_3Al_2\ (SiO_4)_3$.

Pyrope—magnesium-aluminum garnet, $Mg_3Al_2\ (SiO_4)_3$.

Almandite—iron-aluminum garnet, $Fe_3Al_2\ (SiO_4)_3$.

Spessartite—Manganese-Aluminum garnet, $Mn_3Al_2\ (SiO_4)_3$.

Andradite—lime-iron garnet, $Ca_3Fe_2\ (SiO_4)_3$.

Uvarovite—lime-chromium garnet, $Ca_3Cr_2\ (SiO_4)_3$.

This last one, Uvarovite, is very rare.

All of the above have been found in Pennsylvania.

USES OF GARNET.

Garnet is used as an ornamental stone (gem) and as an abrasive, or scouring and cutting material, as garnet paper and as garnet wheels. It is also in use as jewel material for watches. The use as abrasive material has been given under that head; however, its chief reason for this use is its habit of rather easy fracture so that new cutting edges are presented, as the wheel or powder is used.

In color garnets range from the colorless or pale green grossularite to the brilliant dark green uvarovite.

The common garnets are reds and browns. *Pyrope,* a variety used as gem, is often a deep ruby red and is sometimes sold as genuine ruby. It is of inferior hardness and lustre.

LOCALITIES IN PENNSYLVANIA.

Grossularite is found in the Triassic shales in Cumberland county near New Cumberland, in the pegmatite (giant granite) veins in the

quarries near Chester; it is also reported at Hummelstown, Dauphin county. The mica rocks of the lower Susquehanna below McCalls Ferry are at times somewhat full of small red garnets. In the Cardeza collection, now in the University of Pennsylvania, are large masses of granular garnet rock with mica and quartz "from Delaware county." This is suitable for abrasive use.

The chief localities for garnet, however, have been the quarries opened in the gneissic and granitic rocks in Delaware county. The collections in Philadelphia, at the Academy of Natural Sciences and at the University of Pennsylvania, have magnificent specimens taken from these old quarries. Along Crum Creek, in the vicinity of Bishops Mills, at Swarthmore and elsewhere in Delaware county garnets are frequent. In Philadelphia, Montgomery, Berks, Bucks, Northampton and other counties are numerous localities. In Chester county in Pennsbury, East and West Nottingham, Newlin, London Grove, Oxford, East Bradford, Elk and other townships are numerous localities for the iron-aluminum variety.

Near Philadelphia are very many localities which cannot be given here. The quarries along the Schuylkill near Conshohocken, on the Wissahickon Creek, are places which show numerous garnet occurrences, though not commercial ones. The rare chromium garnet has been found in small emerald green crystals at the old Wood mine, in Lancaster county..

At present (1912) garnet is quarried north of Chester for abrasive use; it has been quarried until recently at Chelsea, Delaware county.

GAS. (NATURAL.)

The natural gas obtained in Pennsylvania has been, since it was first exploited, a source of great wealth, as well as a substance of great convenience and practical value.

At the close of the year 1910 there were over 10,000 producing wells in the State; these are chiefly located in the following counties: Elk, Greene, McKean, Warren, Washington, Armstrong, Beaver, Butler, Fayette, Indiana, Venango and Westmoreland.

The question is often asked as to the possibility of finding gas and petroleum in the eastern counties of Pennsylvania, and also in the counties of the central mountain section; in reply to this it may be said that both gas and oil have almost universally been found in those rock formations which do not show much disturbance or serious folding, this folding or fracturing of the rocks seemingly not allowing the gas or oil to be held in natural reservoirs. Moreover, the ancient crystalline rocks have not been, in actual experience, the ones to carry either oil or gas. Some years since a well was sunk in the South Mountain in Adams county to obtain oil or gas, no details of the

drillings were made public and so far as has been stated no gas or oil were found although some evidences of oil were reported as seen at the surface. If either were found in the locality it would be almost, if not absolutely, without precedent as the rock formations are not at all those in which these substances occur.

GLASS MATERIAL: SAND, ETC.

Pennsylvania produces more glass sand than any other State, the amount in 1910 being nearly 450,000 tons.

Glass sand is produced at the present time from Dagascahonda, Elk county; Falls Creek, Clearfield county; at Dunbar, Bellevernon and other places along the Monongahela river; in the neighborhood of Mapleton, Huntingdon county; Vineyard, Mifflin county, and near Oil City, Venango county.

Glass sands have been worked in this State in very large quantity and since Colonial times, the chief sources of such material being from the Oriskany sandstone as in the Huntingdon-Juniata region; river sands and sands obtained by crushing and washing other silica rock.

The substances used for glass making are chiefly quartz sands, which make up most of the mixtures, with addition of limestone, soda or potash compounds, such as crude salt cake; to these are added lead for glass of a highly refractive character.

The process of glass making may be compared to the process of "fluxing" as used by the furnace man to slag out impurities in the furnace; many such furnace slags, as is well known, are of a glassy or vitreous nature.

GLASS-POT CLAY.

Glass-pot clay is a special grade of fire-clay used for making pots in which to melt glass; it is a refractory clay which burns dense at a moderately low temperature, warps but little, and also resists the corroding or fluxing action of the glass.

The following analysis will show the character of such a clay from Layton Station on the Youghiogheny river; it is a clay occurring a few feet below the Upper Freeport coal and doubtless could be worked at other places for glass-pot use.

Glass-pot clay from Layton, Pa.[1]

SiO_2,	64.89
Al_2O_3,	24.08
Fe_2O_3,	.29
FeO,	.21
CaO,	.41
MgO,	.19
Alkalies,	1.03
H_2O,	9.29
	100.39

[1] Ries, U. S. Geol. Survey, Prof. Paper No. 11, p. 41.

GOLD.

Gold has been found in a number of places in Pennsylvania though nowhere in amount large enough to pay working expenses. In the sands and gravels of the Delaware under the city of Philadelphia; at Franconia, Montgomery county; in the copper-sulphide ores of the Gap mines, Lancaster county, at the Phoenixville mines; in the copper bearing rocks of the South Mountain in Adams and Franklin counties; at all of these localities are well authenticated finds of gold. It was reported as occurring in the bed of Brock Creek in Lower Makefield township, Bucks county, in the Philadelphia Times in January 1891. It is not, however, possible to consider here the reported localities for gold in this State, their name is legion.

There are a number of minerals which to the in-expert eye look so much like gold that persons are very apt to be deceived unless possessed of some experience in handling gold ores; moreover some rich ores may not show any gold at all to the eye. Small scales of mica, iron pyrites, yellow scaly iron minerals, and others of a bright yellow color have been among those to deceive persons, so that the inexpert should be exceedingly careful in allowing his interest or his desire for wealth to lead him astray over reported gold finds in this State. It does not lie within the realm of probability that Pennsylvania will ever be a producer of gold in paying amount. Our mineral wealth is very great, but it does not consist in gold and silver. Small amounts may be reported from time to time from the sands and gravels of streams and from the glacial gravels but such deposits are not likely to be more than superficial and of very temporary value.

GRANITE.

There is very little genuine granite produced in this State. Some of that called granite is either "trap" (which see) or a rock known as *gneiss*. Granite properly speaking is a rock made up or composed of grains of orthoclase feldspar, mica (or a magnesia mineral known as hornblende) and quartz; granite possesses no definite layer structure or bedding and breaks or dresses equally well in any direction.

Gneiss is a rock composed often of the same minerals as granite but these minerals are arranged in the rock in such a manner as to produce a well defined layer or bedded structure.

"Granite-gneiss," as the term is used, is a rock which grades from true granite with a granular structure into one with a banded structure and often no sharp line can be drawn between them.

Quartz and mica scists are banded rocks with much mica and some feldspar and are often used in place of granite. The important fact about true granite, and one which should not be lost sight of in

structural work, is the absence of any definite banded or layer structure, so that the crushing strength is not interfered with, by variations in structure of the rock.

Granite has an average specific gravity of 2.65 which in a general way is equal to a weight of 165 pounds per cubic foot. The crushing strength depends partly upon the size of the grain and the minerals present and ranges from 15,000 to 30,000 or more per square inch.

Granite has been reported as from Berks, Bucks, Chester, Delaware, Lancaster, Lehigh, Montgomery and Philadelphia counties. Much of this is undoubtedly "trap," also some is almost certainly gneiss; while even some marble and sandstone have been called granite by quarrymen and exploiters.

True granite does ocur in the State, especially in the South Mountain, also some of the gneisses are so near granite in character that for the most part they may be used as such. There has not been any discovery of genuine granite in Pennsylvania of really large proportions.

GRAPHITE.

Graphite is a mineral form of the element carbon, C. It is a very soft, black mineral with a greasy feel; it is often called plumbago, which is somewhat misleading as graphite does not contain lead in any form. "Lead pencils" are made from graphite, not from lead.

Graphite is found in scales like mica, in flakes, in fibrous form and in very large quantity in graphitic slates and shales. These slates are of less value than the other forms as they are not pure graphite. In addition to the above kinds is what is known commercially as "amorphous" graphite; this is a form of the mineral with apparently no definite structure. These various sorts of graphite have a wide range of uses dependent upon their character.

"One of the oldest and most important applications of graphite is in the manufacture of crucibles for use in the steel, brass and bronze, and other industries. Such crucibles must have good tensile strength and for their manufacture a fibrous or flaky graphite is used, the interlocking of the fibers adding to the strength. Ground Ceylon lump graphite is the material most in favor in the United States for making crucibles, although small amounts of American flake graphite are also used. Amorphous graphite has never been successfully utilized in crucible manufacture, except for very small crucibles." (U. S. Geol. Survey.)

Besides this crucible use and pencil use graphite is used for paints, one American firm alone producing a score or more of graphite paints; it is used as a lubricating medium on wheels, axles, ball bearings, etc.; as a protective covering in foundry facings, electrotyping, glazing and pipe joinings; as stove polish and in electric battery and dynamo construction. Owing to its great importance in the arts the

natural supply is not equal to the demand and graphite is now made artificialy in the electric furnace. It is important, therefore, that new localities for this mineral should be found.

Graphite is generally considered to be the product of chemical and physical changes in rocks subsequent to their original formation; heat and pressure being the means of producing these changes, which are known among geologists as *metamorphism.* At all events the occurrences of graphite are practically confined to those rocks such as schist, quartzite, gneiss, slates, veins in granites, and in limestones, which have altered in whole or in part to marble; and in Pennsylvania will be found in such rocks. It has been reported from many localities and in some instances companies have been organized to exploit them. At present (1912) graphite is systematically mined at Chester Springs, Coventry, Kimberton, Byres, Phoeniville, Chester county. Graphite is found also in scaly form at Williams' Farm near Kimberton; at Boyertown, Bucks county, and elsewhere in the same county, as in the crystalline limestone at Van Arsdale's quarry near the Neshaminy.

Graphite is found, though in very impure form, in some of the layers of phyllite or slate in the limestones of York, Lancaster, Dauphin and other counties where the Cambrian is exposed. These limestones are much used as paint fillers. (See under Mineral Paint.) One of the difficulties of mining graphite is its frequent occurrence with mica. When the graphite is flaky, like mica, it is almost impossible to separate them by flotation in water; some of the finds in this State have been rendered unprofitable because of this. The graphite which is found in distinct veins and in quartzite rocks is the most easily worked. Graphite is supposed to be the result of alteration of some organic substance present in the original rock before the alteration took place. This organic matter carrying carbon is essential to the formation of the graphite; some further discussion of this will be found under composition of coal.[1]

GREENOCKITE.

Cadmium sulphide, CdS, containing cadmium 77.7 per centum. This very rare mineral is found mostly as an orange yellow incrustation with a slightly greenish tint on the sulphide of zinc, spharlerite. Cadmium is a metal somewhat like zinc. It is used in making amalgam fillings for teeth, and in the sulphide form as a pigment. It occurs in this State as incrustations on the zinc ores at Friedensville, Lehigh county. "Formerly cadmium was separated from the zinc at Bethlehem." (Genth, Rep. B. Second Geol. Survey.)

HALITE. SALT. (See potash and salines.)
HEMATITE. (See iron ores.)
HYDROZINCITE. (See lead and zinc.)

[1]For a fuller discussion of the occurances in Pennsylvania, see Report No. 6, of this Survey, "The Graphites of Pennsylvania."

IRON ORES.

The minerals used as ores of iron are the following:

Name of Mineral.	Composition.	Theoretical Percent Iron.
Magnetite,	Fe_3O_4,	72.40
Hematite,	Fe_2O_3,	70.00
Limonite (Brown Hematite),	$Fe_4O_3(OH)_6$,	59.89
Siderite,	$FeCO_3$,	48.27

Limonite includes several other hydrated iron ores such as turgite, goethite and "bog ore."

Siderite is often in common practice called spathic or black band ore, clay-iron stone.

The sulphides of iron are not used as iron ores owing to the high content of sulphur.

Some limonites run very high in manganese and are classed as manganese ores. (see under Manganese.)

In actual practice of iron working it is almost always found that the iron percentage is considerably less than the theoretical amount, this is due to the presence of a certain number of other elements usually called "the gangue"; these are impurities in the ore and must be removed in the refining of iron and steel. These impurities are generally silica, sulphur, phosphorus, lime, magnesia, alumina, and titanium; other elements such as arsenic, chromium, and copper are sometimes present. The magnetites at Cornwall, Penna. carry considerable copper, which is extracted as a valuable by-product.

Iron ores are highly affected in value by the sulphur and phosphorus present, and are, on the basis of the phosphorus, distinguished as Bessemer and non-Bessemer; a Bessemer ore is one which does not carry over 1-1000 per centum of the iron in phosphorus, or one which will produce a pig-iron with not more than 1-10 per centum of phorphorus. However, the modern open-hearth process for steel making has to some extent rendered this classification obsolete and allows the working of iron ores formerly not available for high grade steel making.

IRON ORES IN PENNSYLVANIA

Until the year 1880 Pennsylvania produced more iron ore than any other State in the Union, although even then the amount was not enough to supply the furnaces and foundries of the State and ores were imported from outside to supply the local demand. About 1880 the opening to the market of the Lake Superior deposits caused a readjusting of the ore market for the entire country, and more-over,

some of the older ore workings in this State were exhausted, so that the ore production from Pensylvania showed a decrease. The sources of the ore in the State were of a rather varied character, being representative of all the iron minerals named above.

Siderite was mined in the western portion of the State from a compact layer, 6 inches to one foot thick, resting upon the Vanport or "Ferriferous" limestone; it was in part altered to an oxide or hydrated condition.

These ores above the Vanport limestone are sometimes known as the *Buhrstone ore* from the fact that a layer of flinty matter lies at times above the limestone; and as will be seen from the analyses they are in part carbonate and in part hematite or limonite.

The following analyses by McCreath are selected by Platt to show the average character of this ore from Armstrong County:*

BLUE CARBONATE ORE.

Protoxide of iron,	42.428
Sesquioxide of iron,	2.233
Bisulphide of iron,	.187
Protoxide of manganese,	.799
Protoxide of cobalt,	.010
Alumina,	.916
Lime,	7.150
Magnesia,	1.881
Sulphuric acid,	.030
Phosphoric acid,	.334
Carbonic acid,	32.622
Water,	1.950
Insoluble residue.	9.460
	100.000
Metallic iron,	34.650
Metallic manganese,	.619
Sulphur,	.112
Phosphorus,	.146

ROASTED ORES.

	Per cent.
Protoxide of iron,	none.
Sesquioxide of iron,	65.928
Sesquioxide of manganese,	1.563
Sesquioxide of cobalt,	.020
Alumina,	2.688
Lime,	7.710
Magnesia,	.901
Sulphuric acid	.580
Phosphoric acid,	1.074
Carbonic acid absorbed, Water,	5.365
Insoluble residue,	14.520
	100.349
Metallic iron,	46.150
Metallic manganese,	1.088
Sulphur,	.232
Phosphorus,	.469

RED ORE.

	Per cent.
Sesquioxide of iron,	70.714
Sesquioxide of manganese,	2.421
Sesquioxide of cobalt,	.010
Alumina,	1.491

*Rep. H5, 2' Pa. Geological Survey, p. lxvi. Harrisburg, 1880.

Lime,	7.630
Magnesia,	.547
Sulphuric acid,	.010
Phosphoric acid,	.765
Carbonic acid,	5.230
Water,	7,465
Insoluble residue,	3.860
	100.143

Metallic iron,	49.500
Metallic manganese,	1.686
Sulphur,	.004
Phosphorus,	.334

BROWN ORE.

Sesquioxide of iron,	73.928
Sesquioxide of manganese,	1.344
Sesquioxide of cobalt,	.020
Alumina,	1.532
Lime,	1.610
Magnesia,	.501
Sulphuric acid,	Trace.
Phosphoric acid,	.740
Carbonic acid,	None.
Water,	12.615
Insoluble residue,	8.060

SIDERITE, from Wharton Mine, 2 Miles East of Hellertown, Northumberland Co. (Rep. M2, p. 188, McCreath).

FeO,	54.385	$\}$ Fe = 43.050
Fe_2O_3,	1.071	
MnO,	3.25	= 2.521 Metallic manganese.
CoO,	0.010	
Al_2O_3,	1.457	
CaO,	0.540	
MgO,	0.540	
SO_3,	0.112	= .045 Sulphur
P_2O_5,	0.263	= .115 Phosphorus
CO_2,	35.340	
H_2O, (est.),	.923	
Insol. SiO_2 (?),	2.105	
	100.00	

Siderite was formerly mined quite widely in the western part of the State from beds in the various coal formations, and in the central and eastern sections from the Pottsville and Mauch Chunk formations. Limonite was frequently associated with it.

The chief localities were in the counties of Bedford, Cambria, Clearfield, Fayette, Fulton, Huntingdon, Mifflin, Lackawanna, Lycoming, Somerset; and to a less extent in Greene and Washington counties. Siderite is now mined at the Lehigh Gap for paint ore, *q. v.*

Limonite, (brown hematite); this ore was formerly one of the great sources of natural wealth in Pennsylvania and furnished from almost innumerable banks and pits the ore for the great chain of furnaces along the Lehigh, Susquehanna and Schuylkill rivers, and from the deposits in the western portion of the State, helped lay the foundation for the vast iron and steel industry which has made the fame of Pittsburgh world wide.

Partial analyses of Cornwall ore*.

(A. S. McCreath, Analyst.)

	1.	2.	3.	4.
Metallic iron,	64.900	51.450	48.800	41.900
Metallic manganese,	.158	.072	.057	.194
Metallic copper,	.005	.559	.559	.319
Alumina,	.324	1.080	2.315	4.970
Lime,	1.010	2.600	4.330	2.810
Magnesia,	1.131	6.652	5.531	7.457
Sulphur,	.071	2.459	1.807	.428
Phosphorus,	.014	.010	.018	.019
Silica,	3.980	12.270	12.910	20.910
Phosphorus in 100 parts iron,	.021	.019	.036	.045

*Lesley and d'Invilliers, Ann. Rep. Second Geol. Survey Pennsylvania for 1885, 1886, pp. 532, 533.
1.—Analysis of 115 pieces of niggerhead ore from Middle Head.
2.—Analysis of fine or soft No. 3 ore from west cut, north side, Middle Hill.
3.—Analysis of "No. 1 ore' from east face, Middle Hill.
4.—Analysis of "No. 1 light ore" from west cut south face, Middle Hill.
All the above were dried at 212+ °F. before analysis.

Partial analyses of ores from Berks and York counties.*

	(1)	(2)	(3)	(4)	(5)	(6)
Iron,	43.40	43.00	42.75	39.60	38.05	34.55
Silica,	11.13	14.02	22.10	20.20	16.13	21.21
Alumina, Lime, Magnesia,	18.90	13.86	11.45	19.18	19.77	22.38
Copper,	00.01	00.59	....	00.12	00.56	00.17
Manganese,	00.01	....	....	00.23	00.42	00.21
Sulphur,	00.43	00.53	00.59	1.94	1.14	1.64
Phosphorus,	00.09	00.02	00.01	00.06	00.04	00.03

*Lesley and d'Invilliers, Op. cit. page 537.
(1)—Black ore, 163 pieces, from Warwick mine, Boyertown, Berks county; A. S. McCreath, Analyst.
(2)—Magnetic ore from Island mine, Reading, slope No. 1, Leanord Peckitt, Reading.
(3)—Dillsburg ore from A. Underwood's mine; McCreath.
(4)—Magnetic ore from Wheatfield mine, Berks county.
(5)—Magnetic ore, 25 pounds, from Island mine, Reading; McCreath.
(6)—"Blue ore," 20 pounds, from Phoenix mines, Boyertown; McCreath.

Berks county. The *Wheatfield* group of mines is situated about 7 miles southeast of Reading. The ore is found "in irregular masses, having a general layer like form, interbedded with limestone strata, but the ore bodies are numerous rather than large, and lack of persistency is a marked characteristic." (Spencer). This locality has been studied by d'Invilliers: See. Geol. Survey Penna. D3, pt. 1, 1883. Geology of the South Mountain belt of Berks county. The Wheatfield ores were mined in 1905-06; the ore was reported to be soft and earthy to a depth of 30 or 40 feet, probably due to the decomposition of pyrite in the original ore. The soft ores had a ready sale owing to the absence of sulphur, which is so high in the unweathered ores that they need to be roasted to make them usable in a blast furnace. (op. cit. page 31, Spencer.) "From a practical standpoint deep prospecting in the vicinity of the main workings of the Wheatfield group

would seem to offer better chances for a successful outcome than explorations elsewhere in this vicinity." (Spencer, op. cit. page 35.)

Deposits at Boyertown. These ores occur in narrow area or strip between the Mesozoic to the southeast and the gniesses and sand stones northwest of Boyertown; this strip is 2 or more miles in length but the known ore beds are within an area of less than one-half mile. These deposits are distinctively of the Cornwall type. From the explorations so far made it does not seem possible to arrive at a final conclusion regarding these deposits, but further exploration seems to be warranted. (Spencer, op. cit. pp. 57-61.)

The Warwick, known as the Jones mine, is situated about 3-4 mile east of Joanna; it is now in a flooded and abandonded state.

The iron minerals present in this ore are magnetite, pyrite, and in addition chalcopyrite, a copper-iron sulphide.

YORK COUNTY DEPOSITES.*

"Iron ores like those of the Cornwall mines occur at several localities in northern York county. The principal group of mines is situated about one mile east of Dillsburg, and a second smaller group is located just south of Yellow Breeches Creek near Grantham crossing, on the Philadelphia and Reading Railroad. Specular hematite with some associated magnetite has been worked at Minebank schoolhouse, about 2 miles southwest of Wellsville, and minor pockets and indications of ore have been found at various other localities. Most of these occurrences had been discovered prior to 1873 and are described or mentioned in Report CC of the Second Geological Survey of Pennsylvania and in the Annual Report for 1886.

"The Dillsburg ore field has a greater extent than any of the other districts which furnish ore of the Cornwall type. Ore has been taken from more than 30 openings, including open pits and underground mines, and these workings are distributed over a zone nearly 1½ miles long and from one-fourth to one-half mile wide."

GRANTHAM MINES.

On the south side of Yellow Breeches Creek, near Grantham Crossing, are situated three old mines, known as the Landis or Fuller, the Porter and the Shelley. Outcrops in the railroad cuts and material on the mine dumps show that the deposits at this place occur in Mesozoic strata, which include beds of limestone conglomerate. North of Yellow Breeches Creek the rock is Paleozoic limestone, and just south of the mines diabase appear.

The folowing notes are given by d'Invilliers.*

"The old Fuller or Landis mine is owned and worked by Mr. Shelley, who states that a shaft 80 feet deep passed through diabase to a chimney-shaped bed of ore dipping north-northeast. The same

*Spencer, op. cit. pp. 71-72.

ore was struck 100 feet east by a 40-foot shaft, in which the ore also dips towards the creek. According to Mr. Shelley, there are four or five beds here, separated by short intervals of hard rock of a white color, and not unlike a baked slatey sandstone. In April, 1887, preparations were being made to sink on the outcrop of a lower bed showing about 100 yards south of the shaft.

"Immediately across a narrow ravine to the east of this opening a large amount of ore was formerly raised by Mr. Fuller, and the operation is supposed to have been stopped owing to the occurrence of "Potomac marble," which cuts out the ore for a considerable extent through the mine and along the railroad. This rock shows largely through the field and along the track, where an abandoned cut developed a large body of soft surface ore, resulting from the decomposition of the bed, 5 to 8 feet thick, which was encountered in the bottom of the pit. Mr. Shelley says that there are 13 acres in this property through which no pinching in the ore beds occurs, so far as developed."

Hematite. This mineral is found in various kinds in Pennsylvania, as massive red deposits, as fossil ores with limonite, as specular ore, and as micaceous hematite.

Fossil ore, (dyestone ore) occurs in the following localities: In the Clinton group, from Bloomsburg, Columbia county, and Danville, Montour county, traceable through Centre, Fulton, Juniata, Mifflin, Northumberland, Perry, Snyder, Union and Huntingdon counties of middle Pennsylvania, and thence through Bedford county, to the State line on the south. Fossil ores were also found in the north in Bradford, Lycoming and Tioga counties.

These fossil ores are of several sorts, *hard, soft,* and *block ore;* the following data are taken from Sec. Geol. Survey of Penna., Final Summary Report, 1892, Vol. 2 pp. 750 ff. The center of the fossil ore industry of the State was at Danville and Bloomsburg on the Susquehanna (North Branch), at Frankstown and Holidaysburg on the upper Juniata, at Orbisonia in Huntingdon county, and along the Lewistown valley in Mifflin and Snyder counties. These localities supported furnaces which depended on a mixture of the limestone ores, hard and soft, and the block ore from the sandstone, which in many instances lay between the layers of the limestone. The soft ore was a limonite due to the superficial alteration of the hematite, (the hard ore), while the block ore as stated was a sandstone rich in iron.

Analyses of these ores show the following results, taken from the report above cited.

†Ann. Rept. Geol. Survey Pennsylvania for 1886, pt. 4, 1887, pp. 1513-1514.

	1.	2.	3.	4.	5.
Water,	3.50	7.05	0.00	0.18	0.00
Silica,	19.28	24.11	5.56	6.01	27.28
Peroxide of iron,	67.30	60.49	38.81	28.65	52.23
Alumina,	7.94	2.45	4.34	6.95	8.29
Lime,	0.86	1.12	25.17	29.44	2.43
Magnesia,	0.80	0.43	2.85	2.17	1.54
Sulphur,	0.02	0.02	0.10	0.60	0.17
Phosphorus,	0.47	0.70	0.23	0.15	1.56
Manganese oxide,	....	3.20	....	....	a trace.
Carbonic acid,	....	....	23.00	21.66	....

1 and 2 are the soft ore, 3 and 4 are the hard ores, 5 is the "block."

The Danville ores were first worked in 1839 by D. L. Leavitt; subsequent to 1880 by the Reading company. The working of these ores came to a stop for the same reason that the limonite ores are no longer worked. To quote from Lesley, (op. cit. p. 752) "***the long, rich fossil ore outcrops of Middle Pennsylvania were a source of wealth both to individuals and to the State. Now, still richer and more cheaply mined ores from the Lakes, from Cuba, Spain and Africa, have almost killed the fossil ore industry, and the hard fossil of the deeper parts of the bed is of little or no value."

To say that the fossil ores of the entire State are worked out is however another matter, as there are places where these ores are still to be seen in deposits which seem to indicate some workable value. The deposits are however of very uncertain extent as they are apt to pinch out or run out in non-iron bearing rock. It is rather characteristic of them also to run so high in lime that it is rather profitless to work certain grades of them. However, it would seem to much to say that they are of no probable further value without more extended investigation.

The red hematite deposits of Spang Hill, Berks County, Pa. This locality has been known to carry iron ores for a long time and exploitation pits have from time to time been opened in and about this locality. In the Report D3, Sec. Geol. Survey of Penna., page 359, several open cuts and a tunnel are mentioned at the old mine of Kaufman & Spang, about one mile east of Spangsville; but as the old openings were all closed or fallen in it was not then possible to make an estimate as to the probable value of the red hematites of this general locality. The locality lies east of Reading in a cluster of rounded hills of the South Mountain, in Earl township.

At the present time *The Manatawney Bessemer Ore Company* is making extensive exploitations in the hope of opening up and developing a sufficient body of workable ore to make permanent working a profitable matter. A railroad has been surveyed and is in process of construction to transport the ore to furnace. The grading of this railroad has cut through the several geological formations to

such an extent that a much clearer idea of the general geology of the region may now be had than formerly. As is so frequently the case in the South Mountain the structure is of some considerable complexity. However, the following may be stated in a tentative way as seeming to be probable in the light of the present exposures of the ore rock.

The mass of the ore bearing rock is apparently in intermediate contact between a very highly serpentinized limestone on the one hand; and a series of metomorphosed sediments of a shally character which in turn are in a probable unconformity with a quartzite, *Chickies* or *Hardyston;* the whole has been subjected to several stages of ingeous action as the presence of basic and acid schists and gneisses would seem to show.

Whether these igneous intrusives are anterior to or are responsible for the metamorphism of the sedimentaries, or whether a general subsequent metamorphism altered all of them it is not practicable now to say; the second supposition seems the most probable one. The point is whether these igneous masses have been the original carrier of the iron salts or whether they have altered an iron deposit already present. It has been claimed, or at any rate suggested, for the iron deposits at Manatawney that they are due to segregation or secondary enrichment as a result of the above mentioned igneous action. There seems more reason to believe that the hematite is due to an alteration of an iron deposit formed by precipitation of some iron salt by the limestone above mentioned, although it is not here claimed that this is established as true. A later igneous action is seen in the presence of *diabase* of the fine grained type common in the Trias elsewhere in the State; this diabase is so far as seen entirely unaltered and cuts up through the other rock members present. It has not been reported in the body of the ore rock.

The quartzite is in part of a very pebbly character and in part of a very fine compact nature, as along the Susquehanna River.

The ore itself is a red hematite of a rather siliceous character, in some cases very highly so. So far as may be seen from inspection of the exploitation pits and the ore from the main entry it is rather variable in character as to the silica. Part of it runs as dense, hard, compact hematite, of a dark metallic color, but most of it is associated with considerable free quartz which in some instances is present in lumps or streaks.

Sulphur is present in the form of yellow pyrite in practically all of the ore now shown. It is reported that the ore runs as high as 68 per cent. iron; this while possible in selected samples is hardly a possibility for the main mass of the ore owing to high quantity of visible silica.

Present openings of the ore: These are shafts, drill holes, pits, and a tunnel or main entry extending into the ore bearing rock to a distance of from 75 to 100 feet, at this point a shaft some 40 or more feet deep has been sunk into the ore. At the end of this main entry the distance, vertical, from the surface is about 100 feet, which with a further downward pit of 40 or more feet makes a total thickness of approximately 150 feet down through the ore bearing mass. The exploratory work has been extended to an approximate distance of 800 feet long by 400-500 feet wide by drills, shafts, pits and the main opening above mentioned. Throughout this area the ore is not uniformly present but appears to be more concentrated in a mass extending parallel with the length of the tract. Some variation of thickness is also to be noted, as the ore is not, so far at least as may be seen, of a uniform extent.

Allowing for discrepancies of a considerable extent there would still seem to be a mass of hematite of a workable size, and of commercial value provided the ore is of a grade of purity to compete with the better ores from elsewhere. Of course there is a possibility that the ore when it is more fully opened may not show as much continuity in the mass as is indicated in the present main entry. The borings do not in all cases seem to show an equal depth of lateral extent. That some of the extravagant claims made for this locality are manifestly not true should not however be allowed to hide the fact that present openings show promise of a tract of workable size. Whether or not this ore will in the mass of it show a chemical character to make it marketable is however another matter. In the presence of so much silica the sulphur apparently present would seem to make bessemer working of this ore a doubtful matter. A considerable sum of money has been spent on opening this tract and in constructing railroad connections. It is very much to be desired that the enterprise shown should result in the development of a really valuable ore deposit; such a deposit would be a source of wealth to the State as well as to individuals.

Specular iron ore, (red hematite), occurs in the following localities: Mined with magnetite at Cornwall, Lebanon county, near Durham, Bucks county; near Hanover, at Dillsburg and Wellsville; the Codorous region, York county, (micaceous hematite); with magnetic iron ores in Chester county; some scattering exposures in the York county basin; micaceous iron ore in Catholic Valley; southwest ridge of South Mountain, near Chambersburg, Franklin county, (not mined).

KAOLIN (SEE CLAY.)

LEAD AND ZINC.

These two metals quite commonly are found together in nature and occur also in a great many minerals, comparatively few of which are of commercial use as sources of metal.

The chief ores of lead are as follow: (all have been found in Pennsylvania).

Name of Mineral.	Composition.	Percentage of Lead.
Galenite,	PbS,	86.4
Cerussite,	$PbCO_3$,	77.5
Anglesite,	$PbSO_4$,	68.3
Pyromorphite,	$Pb_3P_2O_8+PbCl_2$,	76.36

The ores of zinc, so far as this State is concerned, are as follows:

Name of Mineral.	Composition.	Percentage of Zinc.
Sphalerite,	ZnS,	67.00
Smithsonite,	$ZnCO_3$,	51.96
Calamine,	$H_2Zn_2SiO_5$,	54.20
Hydrozincite,	$ZnCO_3+_2Zn(OH)_2$,	60.00

Various other zinc ores are occasionally found associated with the above; these are of no importance in this State.

Practically all of these lead minerals, together with some others of a very rare character, have been found at the old Wheatly mines near Phoenixville, and at the Ecton mine; magnificent specimens of the carbonate and sulphate, together with the phosphate, were found at Phoenixville. At Phoenixville, and also at Perkiomen, were found very fine specimens of sphalerite in the old works of the mines; calamine and smithsonite were found in fine specimens in the Friedensville mines.

Other localities for both lead and zinc minerals are:

Galena occurs as follows: Sinking Valley, Blair county, accompanying zinc ores; with pyrite in sandstone, Bradford county; New Britain, Bucks county; Phoenixville mines, Chester county; Pequea mine, Lancaster county (argentiferous); Ecton mines, near Shannonville, Montgomery county; near Pottsville, Schuylkill county.

Smithsonite occurs as follows: Friedensville zinc mines (with calamine and blende), Lehigh county; Sinking Valley, Blair county; Lancaster zinc mines, Lancaster county. Not worked alone as an ore.

Sphalerite (Zincblende) occurs as follows: Friedensville zinc mines, Saucon Valley with blend and smithsonite in limestone, Lehigh county; Lancaster zinc mines and Pequea mine, Lancaster

county, with galena; Sinking Valley, Blair county, with galena and smithsonite (in places); New Britian, Bucks county, with galena; Espy, Columbia county, with lead ores and in considerable quantity; Ecton mines near Shannonville, Montgomery county. No longer worked.

Wulfenite (Molybdate of lead) occurs in the following localities: Lead mines near Shannonville, Montgomery county; Wheatley lead mines, Phoenixville, Chester county; Pequea mines, Lancaster county.

Localities for lead ores were opened in Blair county as early as the Revolutionary War (Pa. State Archives, Vols. 6, 7, 8, 9). In 1875 diamond drill holes were sunk in the Sinking Valley region but the results were not regarded as favorable. (Pa. Sec. Geol. Sur. Rep. T., Platt). The Friedensville locality, Lehigh county, was worked formerly for zinc and considerable spelter obtained; the ore was in part calamine and part sphalerite. No lead or zinc ores are worked at present in this State.

LIMESTONE; LIME; CEMENT ROCK.

Limestone is one of the most important mineral products of the State.

Limestone may represent two distinct types known as *Calcite* and *Dolomite*. These are respectively Calcium Carbonate, $CaCO_3$, for Calcite; and Calcium Magnesium Carbonate, $(CaMg)CO_3$ for the Dolomite.

Normal Calcite is equivalent to

CaO,	56.00
CO_2,	44.00
	100.00

Normal Dolomite, where Calcium and Magnesium are in proportions of 1 :1, is equivalent to

CaO,	30.40	This equals	$CaCO_3$,	54.35
MgO,	21.70		$MgCO_3$,	45.65
CO_2,	47.90			
	100 00			100.00

In actual occurrence limestones grade into innumerable variations as to relative proportions of calcium and magnesium oxides; in common practice a limestone with 5 per cent. or over of magnesia, MgO, is usually called dolomite.

In addition, limestone often carry certain proportions of clay or "shale," when they are known as "argillaceous"; or silica (quartz), when they are said to be "siliceous."

"Lime" is a term applied in common speech to the product of burned or calcined limestone and is the oxide of calcium (or in case of the dolomite a mixture of oxides of calcium and magnesium); thus:

PLATE VII.

A.—Limestone quarried at York for lime and building stone. There is considerable slaty member in this limestone, which is in spots altered to marble. Photograph by F. Ehrenfeld.

PLATE VII.

B.—Fold in Coplay limestone at Coplay.

"The specific gravity of cement shall not be less than 3.10. The cement shall not contain more than 1.75 per cent. of anhydrous sulphuric acid, SO_3; nor more than 4 per cent. of magnesia." (Year Book Amer. Soc. for Testing Materials, 1910, p. 108).

Under the account of the Lehigh Cement district will be found analyses of cement limestones as actually in use. Analyses of the Vanport and Freeport limestones are given under the limestones of Western Pennsylvania. The limestones of Mifflin county, especially at Milroy, have been worked in enormous quantities for blast furnace flux. They have been opened in the past as cement rock quarries but are not now reported to be used for this purpose.

Cement plants are in operation in the Lehigh section; in Mercer county at Sharon; in Lawrence county at New Castle, and Wampum; in Lancaster county, York county and in Allegheny county.

The following analyses of the Cambrian limestone of the York-Lancaster section are given as showing the very high degree of purity which some Pennsylvania limestones possess.

Analyses of Limestone from Quarry West of York.

(Analyses by Dr. Charles H. Ehrenfeld, York, Pa.)

	1.	2.	3.	4.	5.
SiO_2,	0.06	0.05	0.08	0.06	0.56
$Fe_2O_3+Al_2O_3$,	0.06	0.06	0.44	0.50	0.26
$CaCO_3$,	99.70	99.76	98.88	99.33	97.23
$MgCO_3$,	trace.	trace.	0.50	0.15	2.03
Total,	99.82	99.87	99.90	100.04	100.08

No sulphur in any of the above.

Others in the same general district and in Dauphin county run almost pure dolomites, that is normal, and free from iron, silica, etc.

It is probably true that nearly every section of the State has lime suitable for some one of its many uses.

Under glass making will be found analyses of limestones suitable for such uses.

LEWISTOWN LIMESTONE (Lower Helderberg Formation).

The Lewistown limestone and the Trenton (in part Cambrian) of the Sec. Geol. Survey of Penna. are found in the central part of the State in great abundance though not always of equal purity or value.

The Lewistown limestone proper measures 162 feet in thickness in Huntingdon county and 185 feet at Lewistown in Juniata county. These thicknesses are maintained throughout the mountain belt of Middle Pennsylvania, west of the Susquehanna river.

Very exact descriptions of this formation, with measurements of its individual beds, are given in Report F. Sec. Geol. Survey of Penna.

Analyses given below of the Lewistown limestone from Blair and Huntingdon counties are taken here from Report MM. Sec. Geol. Survey of Penna., analyses by A. S. McCreath.

BLAIR COUNTY.

	Baker (Upper)	Baker (Middle)	Baker (Lower)
Carbonate of lime,	95.664	95.089	95.571
Carbonate of magnesia,	1.547	1.581	1.521
Oxide of iron and alumina,	.842	.644	.570
Sulphur,	.103	.029	.027
Phosphorus,	.015	020	.009
Insoluble residue,	2.500	3.000	3.020

Baker's quarry, Altoona; three layers of the limestone.

HUNTINGDON COUNTY.

	1 McCarthy	2 McCarthy
Carbonate of lime,	89.292	47.300
Carbonate of magnesia,	2.557	2.011
Carbonate of iron, Alumina,	1.783	1.667
Sulphur,	.059	.1.6
Phosphorus,	.027	.027
Insoluble residue,	5.300	49.030

[1]C. R. McCarthy's quarry, near Saltillo. Specimen taken one hundred and twenty-five feet from bottom of formation.
[2]C. R. McCarthy's quarry, near Saltillo. Specimen taken as a representative of some of the flinty beds which exist in the series.

The greater portion of Western Pennsylvania is underlain by coal-bearing rocks, in which occur a large number of limestones, though only a few of them attain workable thickness. Following is a list of the principal limestone beds, together with their maximum thickness and approximate positions.

PLATE VIII.

A.—View in Naginey's quarry at Milroy, Mifflin County. Enormous quantities of this stone have been shipped to Pittsburgh for blast furnace use. Photograph by F. Ehrenfeld, 1902.

PLATE VIII.

B.—Limestone and shales with some sandstone over the Pittsburg Coal on the Monongahela River, opposite the town of California. The cliff is about 100 feet high.

LIST OF PRINCIPAL LIMESTONES.

Formation.	Name.	Approximate Stratigraphic Position.	Maximum thickness.
			Feet.
Permian formation, Dunkard or Upper Barren measures,	Upper Washingtou limestoue (No. 6),	Top of Washington formation, 250 to 425 feet above Waynesburg coal,	30
Monongahela formation, or Upper Productive measures,	Waynesburg limestone,	20 feet below Waynesburg coal,	35
	Benwood, or Great, limestone;		
	Upper member, or Uniontown limestone.		18
	Lower member,	120 feet above Pittsburg coal,	90
	Sewickley, or Fishpot, limestone.	Over 100 feet above Pittsburg coal,	30
	Redstone limestoue.	30 to 70 feet above Pittsburg coal,	10
Conemaugh formation, or Lower Barren measures,	Pittsburgh limestone,	20 feet below Pittsburg coal,	12
	Ames.	Midway between Pittsburg and Upper Freeport coals,	6
	Elk Lick, or Crinoidal, limestone.		8
Allegheny formation, or Lower Productive measures,	Upper Freeport limestone.	Below Upper Freeport coal,	28
	Lower Freeport limestone.	Below Lower Freeport coal,	5
	Johnstown limestone,	Below Upper Kittanning coal,	10
	Vanport, or Ferriferous, limestone.	Below Lower Kittauning coal,	22
Pottsville formation,	Upper aud Lower Mercer limestones.	Between Homewood and Conoquenessing sandstones,	4 3
Mauch Chunk formation,	Greenbrier, or Mountain limestone.	40 to 50 feet above bottom of Mauch Chunk,	30
Pocono formation,	Loyalhanna, or Siliceous limestone.	Upper portion of Pocono,	60
	Benezette limestone of Elk Co.		7

WASHINGTON UPPER LIMESTONE.

The Washington Upper Limestone occurs at the base of the Greene formation, Dunkard series, (Upper Barren Measures), sometimes thirty feet thick. It is usually divided into several layers. The upper part is quite slaty and is blue on the freshly exposed surface; the middle layers are dark, almost black, and frequently mottled with drab. They are exceedingly brittle and yield a limestone of good quality. The lower part is ordinarily of a light flesh color, and in point of purity is scarcely inferior to the middle portions.

Its thickness varies from six to thirty feet, being greatest in the central portions of Washington county.

ANALYSIS OF UPPER WASHINGTON LIMESTONE, WASHINGTON CO.[1]

Carbonate of lime,	72.866
Carbonate of magnesia,	3.813
Oxide of iron and alumina,	2.929
Sulphur,	.155
Phosphorus,	.061
Insoluble residue,	17.380

UNIONTOWN OR GREAT LIMESTONE.

This limestone bed lies in the Monongahela Formation (Upper Productive Coal Measures), between the Uniontown and Sewickley coal beds.

[1]From opening one mile east of Washington, at tunnel on Hempfield railroad extension, Washington county. From the middle of the bed.

On the Monongahela river it occurs in two divisions, separated by sandstone or shale; the top member being about fifteen feet thick, and the lower member fifty-two feet thick.

The following analyses will represent the average character of the limestones:

WASHINGTON COUNTY—1 MILE NORTH OF CANNONSBURG.

	Upper layer.	Middle layer.	Bottom layer.
Carbonate of lime,	68.837	48.823	47.080
Carbonate of magnesia,	14.649	20.621	28.528
Carbonate of iron,	3.306	3.625	7.511
Alumina,		3.523	
Sulphur,	.097	.203	.069
Phosphorus,	.049	.051	.127
Insoluble residue,	13.300	22.520	15.750

SOMERSET COUNTY.

	1 Keystone.	2 Saylor Hill.
Carbonate of lime,	72.623	85.732
Carbonate of magnesia,	12.614	5.098
Carbonate of iron,	2.239	2.871
Alumina,	.972	
Sulphur,	.159	.104
Phosphorus,	.005	.037
Insoluble residue,	9.180	6.220

[1]Keystone Coal and Manufacturing Co.'s quarry, two and a half miles south-west of Meyersdale. Hard, compact, bluish grey.
[2]Saylor Hill quarry, three quarters of a mile west from Meyersdale.

SEWICKLEY LIMESTONE.

This is the "Fishpot Limestone" of Prof. Stevenson's Reports K. and KK., underlying the Sewickley coal at an interval of about fifteen feet. It varies considerably in thickness, reaching its maximum on Redstone creek, Fayette county, where it is thirty feet thick and of excellent quality.

The average character of the Sewickley limestone is shown by the following analysis:

ANALYSIS OF SEWICKLEY LIMESTONE.[1]

Carbonate of lime,	80.647
Carbonate of magnesia,	2.217
Carbonate of iron,	1.657
Bisulphide of iron,	1.125
Alumina,	.543
Sulphuric acid,	.052
Phosphoric acid,	.066
Water,	1.010
Carbonaceous matter,	1.250
Insoluble residue,	10.770
	99.337

[1]Oliphant Furnace quarry, Georges township, Fayette county.

REDSTONE LIMESTONE.

This limestone, when present, directly underlies the Redstone coal bed. Its occurrence is very irregular, and its character very variable.

ANALYSES OF REDSTONE LIMESTONE.

	(1)	(2)
Carbonate of lime,	66.471	86.625
Carbonate of magnesia,	17.711	6.152
Carbonate of iron,	5.178	1.825
Alumina,	.812	
Sulphur,	.080	.093
Phosphorus,	.048	.023
Insoluble residue,	9.460	4.040

[1]Lemont Furnace quarry, three miles north-east of Uniontown, Fayette county.
[2]Manasses J. Beechey's quarry, two and one half miles southwest of Salisbury, Somerset county.

PITTSBURGH LIMESTONE.

This limestone underlies the Pittsburgh coal at an interval of about twenty feet. It has a wide range throughout Southwestern Pennsylvania and extends eastward across the Allegheny Mountain, into the Cumberland basin of Maryland, showing also in the Salisbury basin in Somerset county.

ANALYSIS OF PITTSBURGH LIMESTONE.

Carbonate of lime,	82.768
Carbonate of magnesia,	2.875
Oxide of iron and alumina,	2.830
Sulphur,	.156
Phosphorus,	.011
Insoluble residue,	10.327

A. H. Fulton's quarry, at West Lebanon, Indiana county.

UPPER FREEPORT LIMESTONE.

This limestone lies at an interval of a few feet below the Upper Freeport coal in the Allegheny formation.

The average character of the limestone is shown by the following analyses:

ANALYSES OF UPPER FREEPORT LIMESTONE.

	(1)	(2)
Carbonate of lime,	89.821	54.768
Carbonate of magnesia,	1.801	8.627
Oxide of iron and alumina,	1.700	6.930
Sulphur,	.133	.112
Phosphorus,	.027	.017
Insoluble residue,	5.430	27.230

[1]S. C. Hazlett's quarry, two miles south of Jacksonville.
[2]G. Livengood's quarry, three miles east south-east from Blairsville, Indiana county.

ANALYSIS OF UPPER FREEPORT LIMESTONE.

	(3)
Carbonate of lime,	94.643
Carbonate of magnesia,	1.144
Oxide of iron and alumina,	2.720
Sulphur,	.028
Phosphorus,	.015
Insoluble residue,	.990

[3]Kier Brothers' quarry, at Salina, Westmoreland county.

JOHNSTOWN CEMENT BED.

ANALYSES OF JOHNSTOWN CEMENT BED.

	(1)
Carbonate of lime,	78.768
Carbonate of magnesia,	2.421
Oxide of iron and alumina,	3.540
Carbonate of iron,	......
Alumina,	......
Sulphur,	.097
Phosphorus,	.018
Insoluble residue,	13.790

[1]Tybawk's quarry, one mile east from Black Lick station, Indiana county. From main bench of deposit.

	(2)	(3)
Carbonate of lime,	63.969	88.139
Carbonate of magnesia,	4.244	1.854
Carbonate of iron,	4.393 (iron and alumina together)	1.798
Alumina,		.340
Sulphur,	.385	.357
Phosphorus,	.142	.023
Insoluble residue,	24.780	5.640

[2]Zimmerman's quarry, three and a half miles southeast of Somerset, Somerset county.
[3]Wilt's quarry, near Stoystown, Somerset county.

VANPORT LIMESTONE.

This bed, formerly known as the *Ferriferous,* is without doubt the most widespread and available limestone for Portland-cement manufacture in Western Pennsylvania, outcropping over large parts of Jefferson, Clarion, Armstrong, Northern Butler, and Lawrence counties, and appearing occasionally in Northern Indiana, Beaver and Venango counties, but dying out along a line drawn in a northeast-southwest direction through the middle of Indiana and the western part of Clearfield counties. Although not always present, even in those counties where it is best developed, it is the most persistent stratum known in Western Pennsylvania, and therefore a good key to the geologic structure. In stratigraphic position it occurs below the Lower Kittanning coal and fire clay, from which it is separated by sandstone or sandy shales. It is often overlain by a thin bed of limonite, known as the "buhrstone ore bed." (See under "Iron Ore.")

ANALYSES OF VANPORT LIMESTONE FROM ARMSTRONG COUNTY, PA.

	1	2	3	4
Insoluble residue,	3.420	0.790	2.100	0.370
Calcium carbonate ($CaCO_3$),	93.246	96.007	94.185	96.785
Magnesium carbonate ($MgCO_3$),	1.740	1.498	1.483	1.278
Alumina (Al_2O_3),	1.667 (alumina and ferric oxide together)	1.462	2.089	1.000
Ferric oxide Fe_2O_3,				
Sulphur,	....	....	....	.060
Phosphorus,	.032	.034	.03	.029
Thickness in feet,	8 to 10	9	7	8

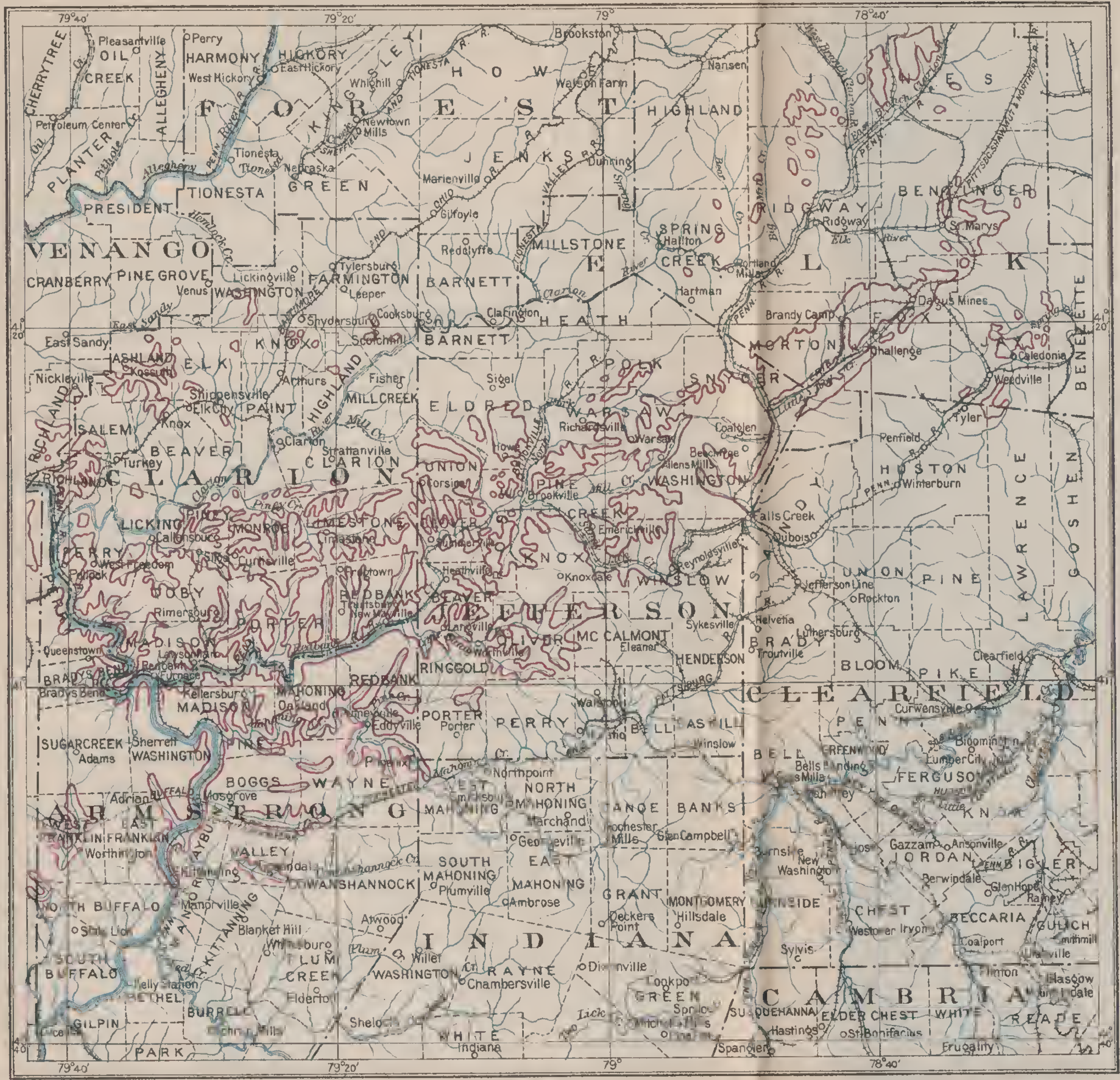
[1]Cowanshannock Creek, west edge of Cowanshannock Township. Sec. Geol. Surv. of Penna., Vol. H5, p. 97; analysis by A. S. McCreath.
[2]Mahoning Creek, at Stewardson Furnace. Op. cit., p. 169; analysis by A. S. McCreath.
[3]Crooked Creek, between Mr. George's and the pottery. Op. cit., p. 64; analysis by A. S. McCreath
[4]Pine Creek Furnace, 6 miles northeast of Kittanning. Sec. Geol. Surv. of Penna., Vol. MM, p. 298.

MAP OF A PORTION OF THE BEAVER VALLEY AND VICINITY
SHOWING OUTCROP OF VANPORT LIMESTONE
BY F.G.CLAPP
1904

From a map published by the Second Geological Survey of Pennsylvania 1893

Scale
10 0 10 20 miles

PLATE X.



MAP OF A PORTION OF THE ALLEGHENY VALLEY AND VICINITY
SHOWING OUTCROP OF VANPORT LIMESTONE
BY F. G. CLAPP
1904

From a map published by the Second Geological Survey of Pennsylvania, 1893

Scale
10 0 10 20 miles

The portion of *The Great Valley* which includes the Lehigh cement section contains the following limestones in ascending order.*

The Allentown Limestone.
The Coplay Limestone.
The Nazareth Limestone.
The Lehigh Limestone.

The Allentown and Coplay limestones are dolomitic while the Nazareth limestone is almost uniformly a calcite, the amount of magnesium carbonate being usually less than 3 or 4 percentum, although it at times runs as high as 22 percentum. *The Lehigh Limestone* or *"Cement Rock"* is the upper portion of the Nazareth limestone and is typically a series of thin beds of a high shaly or argillaceous nature. "The rock is at times grey in color and shaly, breaking into small flat, irregular or pencil shaped fragments,—at times dark drab almost black and distinctly slaty in character".** This is generally used and known in the Lehigh district as the "cement rock." The maximum thickness is scarcely over 200 feet.

In the older State and other reports on the geology of this region, these limestones were referred in part to the *Trenton* and in part to the *Hudson River* formations and the exact geological position of these beds is by no means fully established as yet. That they are not all of one age or series is, however, quite clear.

The Lehigh limestone, or cement rock, has been widely described and known as *Trenton* and in many reports both of the State of Pennsylvania and of the U. S. Government has been so called.

The Martinsburg Shale which succeeds this limestone has long been known as Utica or Hudson River. The details of discussion of these changes of names can not be given here.

E. C. Eckel† in his accounts of the Lehigh district, makes the following classification with analyses:

"The 'Lehigh district' of the engineer and cement manufacturer has been so greatly extended in recent years that the name is now hardly applicable. Originally it included merely one small area about 4 miles square, located along Lehigh River partly in Lehigh county, and partly in Northampton county, and containing the villages of Egypt, Coplay, Northampton, Whitehall, and Siegfried. The cement plants which were located here at an early date secured control of most of the cement-rock deposits in the vicinity, and plants of later establishment have therefore been forced to locate farther and farther away from the original center of the district. At present the district includes parts of Berks, Lehigh, and Northampton counties, Pennsylvania, and Warren county, New Jersey, reaching from near Reading, Pa., at the southwest, to a few miles north of

*Topographic and Geologic Survey Commission of Pa., Report 5, pp. 24 seq., Harrisburg, 1911.
**op. cited p. 30.
†Edwin C. Eckell. Bulletins 225, 243, 260 and others. U. S. Geol. Sudvey, Washington.

Stewartsville, N. J., at the northeast. It forms, therefore, an oblong area about 25 miles in length from southwest to northeast, and about 4 miles in width."

"Within the 'Lehigh district,' as above defined, three geologic formations occur, all of which must be considered in attempting to account for the distribution of the cement materials used here. These three formations are, in descending order, the (1) Hudson shales, slates, and sandstones; (2) Trenton limestone (Lehigh cement rock); (3) Kittatinny limestone (magnesian). As all these rocks dip, in general, north-westward, the Hudson rocks occupy the northwestern portion of the district, while the cement rock and magnesian limestone outcrop in succession farther southeast."

"The composition of the typical shales and slates of the Hudson formation is well shown by the following analyses:

ANALYSES OF HUDSON SHALE AND SLATE IN PENNSYLVANIA AND NEW JERSEY.

	1.	2.	3.	4.
	%	%	%	%
Silica (SiO_2),	68.62	68.00	56.60	a76.22
Alumina (Al_2O_3),	12.68	14.40	21.00	13.05
Iron oxide (Fe_2O_3),	4.20	5.40	5.65	
Lime (CaO),	....	2.68	3.42	2.67
Lime carbonate ($CaCO_3$),	2.34	....	....	....
Magnesia (MgO),	....	1.51	2.30	.93
Magnesium carbonate ($MgCO_3$),	3.76	....	....	....
Alkalies,	3.73	.11	.50	....
Carbon dioxide (CO_2),	....	2.30	2.20	....
Water (H_2O),	4.47	2.70	3.00	....

a Insoluble.
1. East Bangor, Pa., Twentieth Ann. Rept. U. S. Geol. Survey, pt. 6, p. 436.
2. 1 mile northwest Colemanville, N. J. Geology New Jersey, 1868, p. 136.
3. Delaware Water Gap, N. J. Geology New Jersey, 1868, p. 136.
4. Lafayette, N. J. Rept. New Jersey State Geol. for 1900, p. 74.

"*Combination of materials used.*—Throughout most of the Lehigh district the practice is to mix with a relatively large amount of the "cement rock" or argillaceous limestone a small amount of pure limestone, in order to bring the lime carbonate content up to the percentage proper for a Portland-cement mixture.

"In the plants located near Bath and Nazareth, however, the practice has been slightly different. In this particular area the cement-rock quarries usually show rock carrying from 70 to 80 per cent. of lime carbonate. The mills in this vicinity, therefore, require practically no pure limestone, as the quarry rock itself is sufficiently high in lime carbonate for the purpose. Indeed, it is at times necessary for these plants to add clay or slate, instead of limestone, to their cement rock, in order to reduce its content of lime carbonate to the required figure. In general, however, it may be said that the Lehigh practice is to mix a low-carbonate cement rock with a relatively small amount of pure limestone."

ANALYSES OF LEHIGH DISTRICT CEMENTS.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
	%	%	%	%	%	%	%	%	%	%
Silica (SiO_2), ...	21.30	21.96	21.1	20.87	19.06	21.65	22.68	21.08	24.23	24.48
Alumina (Al_2O_3), ...	7.65	8.29	8.0	7.60	7.47	8.09	6.71	7.86	4.80	4.51
Iron oxide (Fe_2O_3), ...	2.85	2.67	2.5	2.66	2.29	2.93	2.35	2.48	1.86	2.68
Lime (CaO), ...	60.95	60.52	65.6	63.04	61.23	63.10	62.30	63.68	63.01	61.33
Magnesia (MgO), ...	2.95	3.43	2.4	2.80	2.83	2.00	3.41	2.62	3.20	2.59
Alkalies (K_2O, Na_2O), ...	1.15	(a)	(a)	(a)	1.41	(a)	(a)	(a)	(a)	(a)
Sulphur trioxide (SO_3), ...	1.81	1.49	(a)	1.50	1.34	1.02	1.88	1.25	1.20	1.41

a Not determined.

The following observations and analyses of both the Nazareth limestone and Lehigh limestone (cement rock) are quoted from The Topographic and Geol. Sur. Commission of Penna., Rep. 5, 1911:

ANAYLSES OF THE NAZARETH LIMESTONE.

No.		$CaCO_3$	$MgCO_3$	No.	$CaCO_3$	$MgCO_3$
1,	....	89.50	1.92	16	92.90	2.10
2,	....	92.20	2.60	17	88.90	2.27
3,	....	94.00	2.27	18	91.30	1.92
4,	....	88.20	1.92	19	92.10	1.92
5,	....	87.80	1.51	20	84.80	1.52
6,	....	93.40	1.92	21	90.60	2.27
7,	....	91.00	3.20	22	65.80	*19.49
8,	....	70.60	†12.94	23	94.00	1.76
9,	....	94.40	1.92	24	90.50	2.66
10,	....	72.20	*11.18	25	92.70	2.66
11,	....	66.50	‡18.73	26	51.30	†22.09
12,	....	90.30	2.43	27	84.70	2.60
13,	....	92.00	2.86	28	70.90	1.92
14,	....	96.60	1.51	29	88.90	2.10
15,	....	95.10	1.92	....	....	....

*4 feet thick.
†2 feet thick.
‡1 foot 6 inches thick.

"Each of these analyses is of a separate bed. The samples were taken from three adjacent quarries located about two miles west of Catasauqua. The beds from which the samples were taken aggregate about 75 feet in thickness, and the samples were taken as numbered from below up. Only the percentages of carbonate of lime and magnesia are given, the remainder being chiefly silica and alumina with some iron."

"The variation in chemical composition of the beds which go to make up the *Lehigh Limestone*, is well illustrated in the thirty analyses given below, which were made from as many samples taken ten feet apart in sinking three drill holes, each to a depth of one hundred feet. These drill holes were made to test the character of the cement rock which lies immediately above the beds of Nazareth limestone, 29 analyses of which are given above."

ANALYSES OF THE LEHIGH LIMESTONE (CEMENT ROCK).

Drill Hole No. 1.

	10 feet.	20 feet.	30 feet.	40 feet.	50 feet.	60 feet.	70 feet.	80 feet.	90 feet.	100 feet.
SiO_2,	18.58	19.76	22.30	21.84	13.30	6.03	12.40	20.90	12.82	15.54
Al. Fe_2O_3,	6.88	7.48	7.60	7.02	2.68	1.80	2.88	4.50	3.26	3.56
$CaCO_3$,	60.76	66.51	63.17	64.08	68.41	86.28	79.06	67.51	74.73	70.76
$MgCO_3$,	3.06	3.36	4.18	4.12	14.11	4.06	4.36	5.28	7.90	8.54

Drill Hole No. 2.

	10 feet.	20 feet.	30 feet.	40 feet.	50 feet.	60 feet.	70 feet.	80 feet.	90 feet.	100 feet.
SiO_2,	20.16	17.12	15.48	15.41	15.60	15.14	23.06	19.42	11.58	18.46
Al, Fe_2O_3,	6.70	8.94	7.74	8.56	7.92	7.74	8.48	7.32	4.40	5.76
$CaCO_3$,	64.26	65.79	69.49	68.32	69.31	68.95	61.55	66.03	76.35	59.93
$MgCO_3$,	4.00	4.70	4.38	4.36	4.29	4.55	3.55	4.23	6.42	14.32

Drill Hole No. 3.

	10 feet.	20 feet.	30 feet.	40 feet.	50 feet.	60 feet.	70 feet.	80 feet.	90 feet.	100 feet.
SiO_2,	19.00	20.40	24.90	19.78	18.42	15.96	23.90	18.32	15.14	13.10
Al, Fe_2O_3,	9.34	8.52	8.64	7.82	8.86	7.66	8.26	7.48	7.30	4.44
$CaCO_3$,	64.89	64.62	60.29	65.34	64.62	68.87	58.75	67.33	70.58	72.29
$MgCO_3$,	4.14	4.24	4.11	4.05	4.47	4.30	3.98	4.39	4.29	8.60

NOTE ON THE LIMESTONES OF PENNSYLVANIA.

Readers of this report may be somewhat disappointed at not finding tables of correlation of the different limestone sections of the State, and also at not finding fuller details in regard to the different beds so that it would be possible, for example, to ascertain the exact equivalents, if any, between the limestones of the Lehigh section and those of the great central mountain portion of the State. If any one does feel this disappointment it is only fair to state that while more detailed information could be given in regard to certain individual places where limestone is found that it is not possible to make a comparative report connecting these details with the possible details of other localities for the simple reason that the data upon which to base such comparisons are not in existence. Chemical analyses are not in themselves sufficient since the variations in any one limestone are often very great.

The Second Geological Survey of the State, which went out of existance some years since, based their reports on the Pennsylvania limestone on the data then on hand. But since then geological knowledge has broadened greatly and there has been no systematic study made of our State by which the various formations, limestone and otherwise, may be properly correlated.

The limestones called in general *Trenton* by the Second Survey are in many cases not only not Trenton, even in the old use of that word, but they are frequently representative of several quite different stages of limestone deposition.

The limestones at Milroy in Mifflin county, for example, undoubtedly represent, even under the older classification, beds of greatly diverse character both chemically and physically, and as to age as well. So that in making a comparison between the limestones of this locality and those of Lancaster or Chester county there is actually no certain basis on which to rest. It will not be possible to have this knowledge until a thoroughly scientific study, based upon modern geological knowledge, is made of all the limestones of the State.

This requires time; but it is very much to be desired that the Commonwealth may be brought into a liberal policy towards our State Survey so that this very important work may be started and carried eventually to completion.

MAGNESIAN MINERALS.

The chief magnesia minerals are:

Magnesite, ...	$MgCO_3$; $MgO = 47.6$ per cent.
Brucite, ...	$Mg(OH)_2$; $MgO = 69.0$

Dolomite, a double carbonate of lime and magnesia $(CaMg)(CO_3)$ in which the percentage of MgO runs from 21.7 in normal dolomite, to as little as 5 per cent. in magnesian limestone. In other words "dolomite" is a term applied to magnesian limestones.

These minerals are all sources of magnesia (MgO) used in the arts and in trade.

In addition there are other minerals such as serpentine, meerschaum, mica, and garnet which, while magnesian, are not commercial sources of magnesia.

MAGNESITE.

This is a rare mineral in this State, most of the occurrences being in the serpentine zones and too small in quantity to be of more than passing interest. Some dolomite is mined and calcined and used for the same purposes as magnesite.

Magnesite has been found in the following places: Wood's mine, Low's mine and adjacent spots in the chrome district, Lancaster county; in Chester county at Brinton's quarry, in East Bradford and Goshen townships; in some abundance at some old quarries near Goat Hill, West Nottingham township; in Lehigh county near Easton and other localities; in Delaware county near Radnor; in Berks county at Spangsville.

BRUCITE.

This beautiful mineral has been found in the State chiefly at Texas, Lancaster county. It has a fine waxy lustre, and is usually of a translucent green color, but is at times pink. It is found in plates, scales and in large flat crystals which scale apart like soapstone.

The following analyses have been published (Genth's Rep. B.):

	A	B
Magnesia,	68.87	66.30
Ferrous oxide,	....	0.50
Manganous oxide,	0.80	trace
Water,	30.33	31.93
Carbonic acid,	....	1.27
	100.00	100.00

"A" is from Wood's Mine.
"B" is from Low's Mine.

Dolomite occurs in small yellowish or pearly crystals in some of the limestones of the York-Lancaster-Dauphin section and doubtless in other places in the limestones. (For dolomite limestones see under *limestones).*

USES OF MAGNESIA MINERALS.

These are used for making fire-proofing material, non-conductors around steam pipes, for refractory brick, for linings in basic steel furnaces; small amounts are used for medical purposes as epsom salts, the sulphate.

MANGANESE MINERALS.

"The principal manganese minerals forming ores of manganese are the following:

PRINCIPAL MANGANESE MINERALS.

Mineral.	Composition.	Percentage of manganese.
Polianite, *a*	MnO_2,	63.2
Pyrolusite,	$MnO_2.n\ H_2O$.	60–63
Psilomelane,	$MnO_2.(MnKBa)O.n\ H_2O$.	45–60
Wad,	Hydrous impure mixture of manganese oxides,	Variable.
Manganite, *a*	$Mn_2O_3.H_2O$,	62.4
Braunite, *a*	$3Mn_2O_3.MnO.SiO_2$,	69
Franklinite, *a*	$(FeZnMn)O.(FeMn)_2O_3$,	Variable.
Rhodochrosite,	$MnO.CO_2$,	47.56
Rhodonite (manganese pyroxene), *a*	$MnO.SiO_2$,	41.9
Tephroite (manganese olivine), *a*	$2MnO\ SiO_2$,	54.3
Spessartite (manganese garnet),	$3MnO.Al_2O_3.3SiO_2$,	33.3

*a*Not reported from Pennsylvania, or doubtful.

"These minerals occurring separately or combined among themselves or with other minerals form four different classes of materials from which manganese is obtained commercially: (1) Manganese ares; (2) manganiferous iron ores; (3) manganiferous silver ores; and (4) manganiferous zinc residuum. Manganese ores consist of various mixtures of manganese oxides, sometimes containing admixtures of manganese carbonate."

"The principal use of manganese ores is in the manufacture of iron-manganese alloys such as spiegeleisen, ferromanganese, silverspiegel, and silicomanganese. The first two of these contain principally iron and manganese; the last two contain considerable silicon in addition. Ferromanganese and spiegeleisen are used in steel manufacture as reducers of iron oxide during the final melting, as recarburizers, and in the manufacture of special steels alone or in combination with chromium, nickel, tungsten, and other steel-hardening metals. Manganese is also used in the formation of alloys with copper, aluminum, zinc, tin, and other metals." (U. S. Geol. Survey).

Manganese ores or manganiferous iron ores are used to a slight extent as fluxes in the reduction of silver, lead, and copper ores.

Maganese peroxide is used as an oxidizer in the manufacture of chlorine, bromine, and oxygen, and of potassium ferromanganate; as a drier in paints and varnishes; as a decolorizer of glass; and in the manufacture of the dry and the Leclanche cells. As a coloring material, manganese is used in coloring glass, bricks, and pottery. Several manganese salts are used in drying cloth and as paints.

LOCALITIES IN PENNSYLVANIA.

In a general way manganese minerals are found in the surface iron ore deposits such as *limonite* ore banks in the counties of Lehigh, Berks and Northampton, Bucks, Adams, Cumberland, Lancaster, York, Blair, Huntingdon, Centre and others. Manganese enters into the composition of umber and sienna and has been reported as such in the Lehigh Paint Ore district, many of the old ore banks of the Lehigh-Northampton-Berks section have yielded *psilomelane, pyrolusite* or other mangansee minerals.

In the collections of The University of Pennsylvania, Philadelphia, are rounded nodular lumps as large as croquet balls of "psilomelane from Morgantown, Berks county."

Calcite containing 13.28 per cent. of carbonate of manganese (Rhodochrosite) is mentioned in Dr. Genth's Report B, as occurring at De Turk's, four miles east of Reading; Rhodochrosite is also reported by the same authority from Cornwall, Lebanon county.

."Wad," Bog Manganese is also of frequent occurrence.

Pyrolusite. This mineral is reported at Edge Hill and Spring Mill, Montgomery county; Zach. Cist. (Am. Journal of Science, IV,

39, (1822), reports it "from the headwaters of Bear Creek, Lehigh and Tobyhannah, Broad Mountain."

Analyses are not numerous as pure pyrolusite is not a frequent mineral in this State.

Psilomelane. This is the most abundant manganese mineral in Pennsylvania occurring as already stated in the "iron ore bank" districts. It has also been noted "in the wash on the slopes of South Mountain a few miles northeast" of the Mercersburg-Chambersburg quadrangle. U. S. Geo. Survey, Folio 170, p. 130, 1910.

The folowing analysis from the mines at Ironton, Lehigh county, may be taken as typical:[1]

Manganese dioxide,	MnO_2,	77.96	
Manganese protoxide,	MnO,	4.32	
Sesquioxide of iron,	Fe_2O_3,	3.66	
Alumina,	Al_2O_3,	7.11	
Oxide of cobalt,		.39	
Oxide of nickel,		trace	
Oxide of copper,		trace	
Barium oxide,	BaO	0.152	
Lime,	CaO	0.770	
Magnesia,	MgO	0.236	
Soda,	Na_2O	.368	
Potash,	K_2O	3.042	
Sulphuric acid,		trace	
Phosphoric acid,		0.149	= .063 per cent. Phos.
Water,		3.980	
Silicic acid,		4.845	
		100.583	

52.631 per cent. metallic manganese
2.562 per cent. metallic iron

Nearly all analyses show cobalt, nickel and barium; these elements are of common occurence in the mineral psilomelane wherever fonnd. The nickel content is rarely high enough to be workable.

While many of these old iron ore banks have been abandoned it is possible that reworking them for manganese-irons would bear investigation.

MARBLE.

Marble is, in the proper use of the term, a crystalline form of lime rock, snch as calcite or dolomite (see limestone) and is usually capable of taking a high polish and of being worked easily into a great variety of carved forms. Trade use has however applied the term "marble" to a great many other rocks of an ornamental character, snch as black or mottled limestones, serpentine and soapstone, lime depositions known as travertine or tufa; the term has even been applied to rocks such as granite and coarse grained trap (gabbro) which are far removed from true marble in chemical and physical character. It is not practicable to give here all the trade varieties of marble, or of materials sold as such. Marble has been worked rather largely in the past in Pennsylvania, especially in the older

[1]A. S. McCreath, Sec. Geol. Surv. of Penna., Rep. M2, p. 213.

and more crystalline limestone formations of the Chester Valley and the highly altered limestones of the Great Valley from Lehigh county to the Susquehanna River. The limestones of the Great Valley have in some places, as in Lehigh, Northampton, Lancaster, Lebanon, York and other counties, altered, under geological processes, partly into serpentine and hence come under the class of marbles known as *verde-antique.* A very attractive variety of this is produced in Lehigh county and put on the market as "verdolite."

At other localities these older limestones have altered into bands of almost pure white marble which, however, are seldom of sufficient thickness to be quarried in large blocks. Inasmuch as there is a constant demand for ornamental marbles in smaller blocks for interior decoration of various sorts and for inlay work it is quite possible that a market might be found for some of these Pennsylvania marbles not now exploited. Serpentine as such is not marble and will be further described under another head.

The marble quarries of the Chester Valley, both east and west of the Schulykill, were opened along the vertical beds of the South Valley Hill and supplied the building demands of Philadelphia until the marble from Vermont came into the market. Part of Girard College is built of Pennsylvania marble and part of Vermont marble; the old Stephen Girard banking house in Third street, Philadelphia, is also built of local marble. (See Final Summary Report, Sec. Geol. Survey of Penna., Vol. 1, page 467).

The Cambrian limestone was formerly worked at Marble Hall near Philadelphia and supplied the stone for the City Hall as well as for other buildings in Philadelphia. It is a blue-white stone.

Black Marble has been obtained from the Ordovician (Trenton) of Lycoming county; "pink marble irregularly veined with green," occurs in the Beekmantown (Ordovician) linestone in the vicinity of Chambersburg, as does also a wavy, concentric "bulls-eye" marble. (U. S. Geol. Survey, Folio 170, 1910).

In the older settlements of Eastern Pennsylvania are many old houses built of the local marbles or crystalline limestone taken from the Cambrian; these houses built before the Revolution are still in admirable state of preservation, showing the great durability of these limestones.

Present marble workings in the State are located at West Grove, Chester county; near Bridgeport and King of Prussia, Montgomery county; at Avondale, Delaware county, where a marble somewhat similar to that quarried at Cockeysville, Md., is worked. This stone has had a considerable sale and is put out in three or more varieties.

MARL.

Marl is an earth formed in large part of calcium carbonate, and is usually derived from the disintegrations of shells, or of lime secretions due to plants or other organic matter. Marl is used mostly as a fertilizing earth in soils low in lime. A bed of marl "estimated to contain eighty acres," was formerly worked at Harmonsburg, Crawford county; it was supposed to be of glacial origin and formed in a swamp or shallow lake. A bed of peat covered the marl to a thickness of two or three feet. The composition of this marl is shown by the following analysis taken from Report MM, Sec. Geol. Survey of Pa., page 365, from which report the above data are taken.

Lime,	49.129
Magnesia,	00.839
Bisulphide of Iron,	00.429
Sesquioxide of Iron,	0.170
Alumina,	00.020
Potash.	00.116
Sulphuric acid.	0.222
Phosphoric acid,	0.023
Carbonic acid,	39.356
Water,	2,190
Carbonaceous matter.	6.510
Silica,	1.052
Total,	100.056

Marl has not been reported as worked in other places in the State nor is it probable that large deposits will be found, as the large deposits in New Jersey are from geological formations which are very slightly present in this State; any occurrences in Pennsylvania will most probably be found as post-glacial deposits.

MICA.

This term covers a large group of minerals which are often in practice divided into two groups known as the "elastic micas" and the "brittle micas." The brittle ones are generally of a vivid green or brown and have little commercial value. They are known among mineralogists as the *Clintonite* and *Chlorite* micas. They have a soft, soapy, and when moist, a very slippery feel and may be mistaken for soapstone, with which indeed they are often associated. Some chlorite or green mica rocks carry also chrome iron and magnetic iron. When associated with chromite these micas often show a pale lavendar or purplish tint, due to oxide of chromium. In fact this lavendar colored mica is a very good indicator for the presence of chrome iron. It is known as "kaemmererite."

The elastic micas are the ones which are of chief commercial value.

All micas possess to a very marked degree the property of splitting into sheets or layers of extreme thinness. In some these layers are elastic and after bending fly back to their flat shape. The green micas are brittle and when bent break. The elastic micas are gen-

erally found in rocks of the granite type or in veins known as *pegmatite* (a coarse granite); the mica rocks include also those known as schists in which, however, the mica is in particles too small for use in sheet form.

In *Pennsylvania* the mica rocks are confined exclusively to the southeastern section; there are none west of the South Mountain except as occasional glacial bowlders or pebbles may show fragments. Such occurrences are accidental and superficial and possessed of no permanency.

"The commercial demand has practically been supplied by two varieties, muscovite and phlogopite; but a small quantity of biotite has been used.

(Phlogopite is a Rare Mineral in Pennsylvania.)

"Muscovite, called "white mica," is a silicate of aluminum and potassium containing water; plogopite, called "amber mica," is a silicate of magnesium, aluminum, and potassium; biotite is a silicate of magnesium, iron, aluminum, and potassium (It is known as "black mica.") Phlogopite and biotite may be placed at opposite ends of a chemical series and may grade into each other by variations in the percentage of iron present. In thin sheets muscovite is nearly colorless, phlogopite generally yellow or brownish, and biotite dark brown to black, or brownish green. In sheets of one-sixteenth of an inch or more in thickness muscovite may be colorless, white, gray, yellow inclining to amber, red, brown, or green, phlogopite may be yellow, brown, or black, and sometimes coppery; and biotite is black. Muscovite of a reddish color is often called "rum" and "ruby" mica. The luster of muscovite is brilliant and glimmering on fresh surfaces, and that of phlogopite is less brilliant and more silvery or pearly. (These thin sheets are all very elastic).

USES.

"Mica has a wide commercial application, both in the form of sheet mica and of ground mica. The most extensive use of sheet mica is in the manufacture of electrical apparatus, but a considerable quantity is still used in the glazing trade, for stoves, for gas-lamp chimneys, for lamp shades, etc. The demand for mica for glazing is small and only the best quality and the larger sheets are thus used. Both large and small sheet mica is used in the electrical industry. 'Micanite,' or built-up mica board, for the manufacture of which small-sheet mica can be used, is substituted for large-sheet mica in much electrical work. Mica serves as a perfect insulator in various parts of dynamos, motors, induction apparatus, switchboards, lamp sockets, and nearly every variety of electrical appliance.

"The domestic or muscovite mica is satisfactory for all insulation except for commutators of direct-current motors and dynamos built up of bars of copper and strips of mica. For this purpose no mica

is as satisfactory as the phlogopite or 'amber mica.' This mica is of about the same hardness as the copper of the commutator segments and therefore wears down evenly without causing the machine to spark."

"A large quantity of scrap mica—small sheets and the waste from the manufacture of sheet mica—is ground for different uses. Among these are the decoration of wall paper and the manufacture of lubricants, fancy paints, and molded mica for electrical insulation. Ground mica applied to wall papers gives them a silvery luster. When mixed with grease or oils finely ground mica forms an excellent lubricant for axles and other bearings. Mixed with shellac or special compositions ground mica is molded into desired forms and is used in insulators for trolley wires. Ground mica for electrical insulation must be free from metallic minerals. Mica used for lubrication should be free from gritty matter. For wall papers and brocade paints a ground mica with a high luster is required, and such luster is best obtained by using a clean light-colored mica and grinding it." —(U. S. Geological Survey).

In chemical composition the micas are of very complex character. They are made up of silicic acid combinations of potash, soda, lithia, magnesia, iron and water with alumina. The chief ones found in this State are

Muscovite,—potash mica.
Biotite,—magnesium—iron mica.
Phlogopite,—magnesium mica.

Chorites, green micas, and some alteration products of mica known as *Vermiculites,* upon heating swell apart and expand very much in bulk. *Damourite* and *sericite* are names applied to minute crystal scales of mica, mostly muscovite, occurring in quartz schists, slates, mica schists and feldspar rocks. These are often very silky in lustre and appearance and being frequently smooth and slippery are mistaken for soapstone. Sericite is sometimes found in mineral paints.

MUSCOVITE.

In *Delaware* county at the quarries near the city of Chester and at Leiperville; at Dutton's Mills, in Concord, Middletown and other townships, Muscovite has been found in good crystals.

The chief locality in the State for mica has been in Pennsburg township, Chester county, where some very beautiful masses have been found as large as 12 to 14 inches in diameter (Genth, Report B.). In the same county at Unionville and West Chester are other localities. Muscovite occurs also in the crystalline schists and slates as far west as the Susquehanna.

In and about Philadelphia, in Fairmount Park, Falls of the Schuylkill, in quarries in West Philadelphia, in Germantown, Chestnut Hill, Frankford, and in fact in practically the entire range of the city, micas such as muscovite and biotite have been found wide-spread, though not in sheet form for commercial use. Most of the quarries mentioned in the older State survey reports are built over or long since abandoned. The Gneiss quarries at 69th Street and Arch and Race Strets, Philadelphia, often show fair sized scales or crystals of biotite.

Phlogopite has been stated to be rare in the State. It has been found at the Van Arsdales, Bucks county, quarry in crystalline limestone with graphite, at lime quarries in East Marlborough and New Garden townships, Chester county, and at the old mines at Gap, Lancaster county.

Biotite has been reported at many of the localities for muscovite; it is found in association with molybdenite at Frankford, Philadelphia, at the iron mines at Rittenhouse Gap, Berks county, and in general in the feldspar and muscovite districts.

In prospecting for mica it is well to bear in mind that the large sheets are found in veins of giant granite or pegmatites, while some commercial mica is found in small plates and has a market value it is usually found in connection with the larger sheets and is not generally of itself of workable value.

MINERAL PAINTS; PAINT ORES.

The term "Mineral Paints" includes a considerable variety of materials used for making pigments, paint fillers, mortar colors, brick colors, linoleum colors, and a number of other paint purposes. Some of these mineral paints may be used directly after grinding and mixing in oil or water, others need to be roasted, ground, sifted and treated through a series of processes, depending upon the original character of the raw substance and the nature of the colors desired in the finished product. They are of great importance in Pennsylvania.

"Paint ore" as the term is generally used, is the natural raw product such as shale, the mineral siderite (iron carbonate), or other substance, generally needing roasting and grinding to produce the product.

Natural compounds of iron and manganese supply the basis of most of the substances used as mineral paints so far as the color is concerned, though in addition to these barite, or "heavy spar," is used for white pigments; black shales, graphite or graphite shales or slates for black or slate colors.

Other materials such as clays, whiting, asbestos, soapstone, sometimes used as "extenders," do not properly come under the head of

mineral paint or paint ores, as they impart no color though they may be useful as fireproofing additions to the paint. (J. H. Pratt, "Mineral Paints," in Mineral Resources of U. S., 1904).

Mineral paints may for the purposes of comparison be classified as follows, though the divisions in practice overlap:

(1) METALLIC PAINTS.
- Hematite (reds)
- Limonite (browns)
- Ochre, Umber, Sienna — in part, when used raw
- Siderite (after roasting)
- Cinnabar (vermillion); does not occur in Penna.

(2) PAINT ORES.
- Ochre, Umber, Sienna — when not pure, and needing roasting, grinding, and sifting
- Siderite (carbonate of iron)
- Paint shales (including limestones and slates)

(3) MISCELLANEOUS PAINT MATERIALS (fillers and extenders).
- Barite (Barium sulphate), Mineral white
- Culm (coal refuse)
- Graphite
- Mica (soapstone)
- Oyster-shell lime
- Whiting (chalk, marble); or gypsum

(4) BY-PRODUCT PAINTS.
- Blast furnace dust
- Blue billy (roasted pyrite)

(5) CHEMICALLY PREPARED PAINT.
- Zinc White, Venetian Red, Indian Red, White lead, etc. — not considered in this report

Metallic paints comprise red and brown pigments made directly by simple grinding from certain ores of iron, manganese or other metals. In the case of natural carbonate of iron, known as siderite, a preliminary roasting is required. The minerals used as metallic paints are *hematite*, red oxide of iron, Fe_2O_3; *limonite*, a hydrated oxide of iron yielding when ground brown tints. These two minerals, more particularly limonite, together with turgite and goethite (hydrated iron oxide) when occuring in a naturally powdered form are often spoken of as *ochre*. *Umber* and *sienna* are sometimes used in the raw state as metallic paints, though generally classed under paint ores.

In addition to the above certain metallic paints are made from by-products in metallurgical or chemical manufacture, such as Indian red made from roasted copperas obtained as a by-product from "pickling" iron or steel wire, and "blue billy" a purplish oxide of iron formed as a by-product in the manufacture of sulphuric acid from iron pyrites. These are ground and used as pigments.

HISTORICAL NOTE.

Ochers and other paint ores have been worked in Pennsylvania since Colonial times though references to early uses are not frequent. Reference is made to ocher and paint ores in a book which is now very rare and little known, published in 1787. This is the *"Beyträge zur Mineralogischen Kenntniss des östlichen Theils von Nord Amerika und seiner Gebürge. Erlangen 1787,"* by Dr. Johann David Schöpf, who in 1783 travelled through the eastern part of North America making particular reference to the occurrence of mineral wealth. The following is a translation of a part of Dr. Schöpf's remarks concerning ochers, clay, etc., in Pennsylvania, on pages 138 and 139: "Clay deposits of various sorts, qualities, colors and refractoriness are frequent here and there in the low lying districts, and valleys at the bottoms and slopes of the hills . . . there are rather fine porcelain clays, ochers and others which approach to Spanish brown or at least may be used for paint."

Dr. Schöpf does not particularize the localities in Pennsylvania but a careful search through the early colonial records of Pennsylvania would doubtless show more exact localities and references to the early use of such material. In *Hazard's Register of Pa.,* (Vol. II., Nos. 2 and 6, Philadelphia, 1828) are references, among other Pennsylvania minerals, to what were in all probability openings for ocher. These references are quoted in the "Register" from articles in the *Journal of the Academy of Natural Sciences,* Philadelphia, for 1829 and also from *Silliman's Journal.*

Ocher as commonly understood is a "native yellow to brown earth consisting of iron peroxide and water with varying proportions of clay used as a pigment and as a paint," or "any metallic oxide occurring in an earthy or pulverized form." (Standard Dictionary). This idea of an ocher as a natural powdery form of pigment has, in actual practice in Pennsylvania and elsewhere been erroneously very much enlarged in its scope to include shales, slates, and iron ores which when artificially ground to a powder resemble the natural product. This error is natural enough as it is not a matter of importance to the paint mixer whether the pigment supplied him in a powdery form was found so naturally or whether it has been artificially made by grinding a shale, so long as he has a uniform product with which to produce the paint or color.

Many of the so-called ochers on the market today produced in Pennsylvania are made from shales or iron ores which have been calcined to produce the color and carefully ground to powdery form. These are not ochers at all in the true sense of the word. These shale and bedded ochers are at times lighter in color than the true ochers. Recently Professor B. L. Miller (Bulletin 470, U. S. G. S.) has called

attention to the great variety of shales which are mined in Pennsylvania and which are spoken of frequently as ocher, these are properly speaking paint shales.

The bases of ocher proper are the minerals of the type of limonite or goethite which are oxides of iron chemically united with water; also the mineral hematite, an oxide of iron without water. Limonite and goethite produce browns and yellows, while hematite produces reds, as does also turgite, a hydrous oxide of iron sometimes present.

The base in which these minerals are held is the mineral clay. Sand and other objectionable impurities are often present.

UMBER AND SIENNA.

These pigments are analageous to the ochers and represent a series of earthy pigments in which ores of manganese produce the peculiar tints. In fact both manganese and iron are usually present in umber and sienna.

Umber and sienna are used in two states, "raw," and "burnt." Raw umber is brown or drab. Burnt umber is a reddish brown color and is richer than the raw umber. Raw sienna is brownish yellow, while after being burnt it possesses a strong reddish color: "burnt sienna."

The chief uses for umber and sienna are for tinting paints although they may of course be used for general pigment purposes.

The following analysis of ocher from near White Haven, Pa., shows characteristic low grade ocher. "The ocher is a soft crumbling rock chiefly of a buffish yellow color."*

ANALYSIS OF THE OCHER.

Silica,	57.36
Protoxide of iron,	1.62
Peroxide of iron,	2.94
Alumina,	27.44
Sulphate of lime,	1.93
Sulphate of magnesia,	0.66
Water,	0.85
Organic matter,	4.50
Total,	97.30

Analysis by Hugh Hamilton.

It is evident that the substance here is a material of a clay character and is not true ocher, but a shale; the color is due to the small amount of iron oxide present.

*OCHER DEPOSITS OF EASTERN PENNSYLVANIA.

"The principal ocher belt in Pennsylvania is a comparatively narrow strip extending from Reading to Allentown and approximately following the line of the East Pennsylvania branch of the Philadelphia and Reading Railroad. The district is comprised in the Read-

*Annual Report, Sec. Geo. Surv. of Penna., 1886, Part 4, p. 1316.
*U. S. Geol. Surv. Bull. 430, contributions to Economic Geology, 1909, Part I.

ing, Slatington, and Allentown quadrangles of the United States Geological Survey and lies in the counties of Berks and Lehigh.

"The Reading-Allentown ocher occurs in the Shenando limestone, of Cambro-Ordovician age. It is a residual deposit and was formed from the iron in the limestone during its disintegration.

"The Moosehead ocher occurs as an original bedded deposit in the Mauch Chunk shale. It is of low quality with respect to its iron content.

"The highest grade runs from 68 to 72 per cent. Fe_2O_3. It can be burned on the premises when the demand calls for it, but the greater part of it is put on the market after being ground."

ANALYSES.

"The following analyses, secured from Henry Erwin & Sons, represent the composition of typical finished ochers. The first three are probably mixtures containing foreign ochers, but the fourth (Topton) is a local product:

Analyses of ochers.

	SiO_2.	Fe_2O_3.	Al_2O_3.	CaO.	$CaSO_4$.	MgO.	MnO.	S.	P_2O_5.	H_2O.
Easton ocher, ...	.39.70	.37.64	.13.26	......	......	1.37	......	......	......	7.83
"Pure Prince's Brown, ...	.32.8	46.89	10.76	3.00	......	1.52	1.39	0.5 to 2.0	Tr.	......
"Light red oxide,"	2.05	37.29	......	......	57.65	......	......	......	......	.10
Topton ocher, ...	55.50	17.49	18.66	......	......	......	......	......	......	a8.35

aCombined.

Analyses of ground slate and sienna.

	SiO_2.	Fe_2O_3.	Al_2O_3.	CaO.	MgO.	K_2O.	Na_2O.	MnO.	H_2O.
Ground slate, a	58.84	6.50	19.04	1.60	1.50	2.47	1.75	......	......
Italian sienna, ...	19.23	74.24	1.32	0.48	Tr.	......	......	0.50	b4.23

aLoss on ignition, 7.24. bCombined.

"The following analyses for ferric oxide were made in the laboratory of the department of geology at Lehigh University by the writers:

Percentage of ferric oxide (Fe_2O_3) in ochers.

Finished ocher (Bear Bros., Breinigsville, Pa.), ...	19.50
Finished burnt ocher (Prince Metallic Paint Co., Alburtis, Pa.),	47.32
Finished ocher No. 2 (Henry Erwin & Sons, Topton, Pa.), ...	II.85
Finished ocher No. 4 (Henry Edwin & Sons, Topton, Pa.), ...	18.42
Finisher ocher (Keystone Ocher Co., Fleetwood, Pa.), ...	27.77
Finished ocher (Luzerne Ocher Mfg. Co., Moosehead, Pa.), ...	6.26.

PAINT ORES.

Paint ores are generally distinguished from ocher, umber, sienna and other metallic materials as being those substances which need a treatment somewhat similar to the treatment of other "ores" to obtain the desired product. The original paint ore is a natural rock or mineral possessing either some particular color of its own which is used to produce a paint or tint of that color, or else the ore contains some iron or manganese mineral which upon being roasted will change to a different and also a more permanent color.

The process of roasting is needed also in most cases to expell from the ore any materials present which are not of a permanent character and which after being mixed in a paint might decompose and seriously impair the value of the paint.

SIDERITE PAINT ORE.

Carbonate or iron known as *siderite* is a common paint ore and is typically displayed in the Lehigh Gap section.

The actual paint ore or siderite in the raw state not uncommonly has a striking resemblance to limestone though harder and decidedly heavier. Along natural cracks in the beds the ore is often streaked with brownish or reddish stains from the oxidation of the iron; when exposed on the surface it weathers out into roundish hard lumps of a brownish color known as iron stone or "clay iron stone." This is not uncommon in the outcrops along the so-called "ferriferous limestones" (Vanport) of western Pennsylvania where it has been mined in the past as an ore of iron.

The Lehigh paint ore[1] "in its raw state has a dull metallic blue color; is fine grained arenaceous and quite hard. There are occasional occurrences of iron pyrite (sulphide of iron). The ore when roasted and ready for market is in the form of a very fine powder almost entirely devoid of grit and in color is a very rich dark reddish brown."[1]

Partial analyses of crude *"paint ore"* from Lehigh Gap Dist.[2].

Metallic Iron,	33.00 per cent.
Metallic Manganese,	0.01
Silica.	25.00
Carbonic acid,	25.00

The following is the composition of the ground *paint* from the Lehigh District.[3]

Fe_2O_3,	.41—47 per cent.
SiO_2,	32—37
Al_2O_3,	9—11
CaO,	.1—3
MgO,	1.7—3.5
MnO,	0.35—1.8
P_2O_5,	14—.17
S,	.5—1
CO_2,	1.5—2.5
H_2O,	.6—.9

[1]Hill, Sec. Geological Survey of Penna., Annual Report, 1886, Part 4, p. 1405.
[2]U. S. Geol. Surv. Bull. 430, p. 449.
[3]Idem., p. 453.
See under *Siderite* for other localities.

PAINT SHALES.

For the following details of the working of paint shales in Pennsylvania we are indebted to the work of Prof. B. L. Miller above referred to. We quote as follows: (Bull. 470. U. S. Geol. Survey, 1911.)

"For certain purposes pigments of low tinting value, such as colored shales, have been found to be equal to those of more uniform composition and deeper color. In the manufacture of oilcloth and linoleum the mineral coating on which the color patterns are printed and also the under surface can be prepared as well from yellow and red shales containing only a small percentage of iron as from yellow and red ochers in which the iron content is much higher. Singularly the paint that is applied to a fresh surface of wood or metal primarily for the purpose of filling the pores and small cavities in order to make a smooth surface on which later coats of paint are spread can be manufactured from materials with low tinting value. Black, red, and yellow shales are utilized for these purposes, and the materials when prepared for the market are known as paint fillers.

"The mineral composition of the shales used as pigments is varied, but they are characterized by the absence of any minerals that readily decompose on exposure to atmospheric action. The minerals present must be inert and they must possess the desired color. The basis of all the shales is hydrated aluminum silicate (clay), together with considerable silica in the form of quartz, the whole colored by iron, either in the hydrated form (limonite) or in the anhydrous condition (hematite), by graphite or amorphous carbonaceous matter, by manganese oxide, or by some other colored constituents. Sericite is not uncommonly present and in many of the paint shales of Pennsylvania is a prominent constituent.

"Besides the mineral composition it is necessary to determine the amount of linseed oil required for each pigment, as in the cheaper paints the oil costs much more than the dry colors and the materials requiring the minimum amount of oil are preferred by the manufacturers of mixed paints. Many of the claims of superiority of one product over another are based on the lower absorption of oil."

BLACK SHALES.

Black shales are worked and in a ground form are sold as "Mineral Black" which[1] "is a pigment made by grinding a black form of slate. It contains a comparatively low percentage of carbon and consequently has low tinting value. It finds use as an inert pigment in compounded paints, especially for machine fillers. The pigment has a flocculent appearance, the particles showing a strong tendency to mass."

Black shales, black limestone, and black slaty rocks are widespread in Pennsylvania and have been used for black filler as stated. The

[1]Bull. 29 Sci. Section Paint Manufacturers Assn. of U. S., P. 35.

refuse from the slate quaries and culm banks of the coal mines have also been utilized.

BLACK SLATES OF LEHIGH AND NORTHAMPTON COUNTIES.

The Martinsburg shale in Lehigh and Northampton counties contains two belts of slate that have long been worked for roofing slate, blackboards, billiard-table tops, etc. A considerable amount of the refuse slate from these quarries has been sold to paint mills throughout the State and some has been shipped as far as Chicago.

H. D. Rogers[1] described some slate in the vicinity of Nazareth that was worked for use in paint many years ago.

BLACK SHALES AND COAL OF THE COAL REGIONS.

The black shales of the 'Coal Measures' have also been used in the manufacture of paint to a minor extent. Culm has also been used, and a few years ago black paint was made from the outcrops of disintegrated coal in the Schuylkill region near Pottsville.

YELLOW SHALES.

Yellow shales occur in many places throughout the State and at several geologic horizons, but particularly in the Martinsburg and Mauch Chunk shales. The color is due to small per cents of oxides of iron.

In a number of places these shales have been utilized in the manufacture of paint, and when finely ground and mixed with oil they are very serviceable. Their principal use, however, is in the manufacture of oilcloth and linoleum.

Yellow shales are dug in Berks County from the Martinsburg formation (Hudson river) near Perry. In Carbon county at Slatington and Hudsondale. At Rockport and Penn Haven yellow shales, usually from the Mauch Chunk, are dug for paint; in Luzerne county are extensive workings of shales; yellow and of other colors.

YELLOW SHALES OF WYOMING COUNTY[2].

Yellow shales of the Catskill formation of North Mountain, Wyoming county, have been tested by paint experts and pronounced valuable for paints, so far as known, however, they have never been utilized.

RED SHALES.

Red shales are especially well represented in the Martinsburg ("Hudson river"), Catskill, and Mauch Chunk of the Paleozoic and the Brunswich shale of the Triassic. Near Greenwald, Berks county, it contains enough fine-grained *sericite* (a minute scaly form of mica)

[1]Geology of Pennsylvania, Vol. 1, 1858, p. 249.
[2]Eng. and Min. Jour., Vol. 26, p. 439.

to produce a soapy or talcose feeling when rubbed. On this account the material produced by the company is sold under the trade name 'talckene.'

OTHER POSSIBLE SOURCES OF PAINT ORES AND FILLERS.

The following formations are worthy of note as affording probable sources of paint products.

THE CAMBRIAN.

The shales and slates of this formation in the southeastern counties of the State are in some places free enough from grits and other impurities to be worth experimental investigation.

The *limestones* of the same formation, described as Trenton in the Second Geological Survey, and occurring in practically the same districts as above are frequently characterized by graphitic slates or shales suitable for paint use.

PAINT ORE IN PERRY COUNTY.[1]

In a few places in Perry county as at Gibsons Rock the Oriskany Sandstone is overlaid by beds of iron ore; these have been utilized as paint material similar to the product of the Rocky Ridge in the Lehigh Gap.

The *Clinton Fossil Ore* beds in Perry, Juniata, Mifflin, Blair, and other counties are available for paints, mortar colors, and as Metallic Paints. The various county reports of the Second Geological Survey show fully the available outcrops of these beds.

In Wyoming and other northeastern counties the *Catskill* formation contains many beds of red shales as do also the shales in the *Conemaugh* and *Allegheny* formations in the counties of the western part of the State where these formations occur. In *Somerset* county along Paint Creek the red shales have been used for paint filler. The *Triassic* red shales in the S. E. section of the State are not as yet exploited.

MORTAR COLORS.[2]

"*Character.*—In making mortar colors the dry-color makers utilize also a wide variety of materials, and as the mortar colors are marketed they are probably mostly muxtures. Some iron oxide is used in their production, some "blue billy" ore, considerable ground slate or shale, and considerable culm from coal washeries. The colors are various shades of red, brown, purple, blue, and black, and the material is used for tinting mortar, cement, and concrete."

Most Pennsylvania paint ores and shales carry appreciable quantities of clays and lime and magnesia, which as is well known occur in hydraulic cement. These elements so far from being an objection are of great value in producing a paint which hardens under water and does not fade or scale and is in general remarkable for durability.

[1]See Geological Survey of Penna., Final Summary Rep., Vol. II, p. 1184.
[2]E. F. Burchard, Mineral Res, U. S. 1910. Washington, 1911.

This natural presence of cement material in Pennsylvania mineral paints is especially worthy of remark since the artificial introduction and use of hydraulic cements into paints is covered by patent. The following is quoted[1] "H. Loesner has patented (English Patent no. 28,484, 1897) a method for increasing the moisture resisting power of pigments, which consists in grinding the pigments in linseed oil in the presence of a certain proportion of hydraulic cement or cement diluted with sand. Precautions are taken to prevent the cement from absorbing water before the paint is applied to the iron work, so that when the film is finally exposed the new ingredient is caused to set slowly by means of the moisture in the atmosphere, producing at last a thin layer of hardened cement or cement mortar embodied in a paint of ordinary composition. The incorporation of the cement is said not to interfere with the proper spreading of the pigment, which is claimed to be absolutely damp-proof and permanent."[2]

MOLYBDENUM AND TUNGSTEN.

Minerals carrying these metals are much sought after for the purpose of making special steel alloys. While minerals carrying these metals are rare in this State, they have been found and in the case of one, Molybdenite, further search may perhaps yield available supplies.

Molydenum minerals are *Molybdenite*—MoS_2=60 per cent. Molybdenum, a blue-black soft mineral in flake or scaly form, like graphite; when rubbed on paper it makes a greenish colored streak.

Molybdite=66.7 per cent. Molybdenum; occurs as yellow coatings along with the preceding minerals; it is a molybdate of iron.

Wulfenite, a lead Molybdate which is rare. Found at the Ecton mine, Montgomery county, and the Phoenixville mine in Chester county, neither of which are now worked. This mineral is usually in square, yellow to orange-colored plates.

Stolzite, a lead tungstate is found along with the preceding.

Molybdenite occurs in the talc-serpentine belt of Lehigh and Northampton counties above Easton, (Rep. 5. Topographic and Geological Survey, 1911, p. 16.) It occurs also in Philadelphia, notably at Frankford in the gneiss; in quartz near Chester (Genth. Rep. B. Sec. Geol. Survey); in Berks county in the magnetite iron ores of Rittenhouse Gap; and at Zions Church near Reading. Some Molybdite may be found with the above. While interesting specimens have been found of Molybdenite, no locality has yet given workable deposits.

Scheelite, calcium tungstate, a white shiny mineral with a very high specific gravity has been reported from the eruptive rocks, rhyolite, in the South Mountains, Adams county. The scheelite occurs in minute masses together with piedmontite. (G. H. Williams, Amer. Jour. of

[1] Mineral Industry, Vol. 7, p. 535, N. Y., 1899.
[2] For a fuller discussion of the mineral paints and paint ores, see Rept. No. 4, of this Survey: "The Mineral Pigments of Pennsylvania," by B. L. Miller.

Science, 3d ser., vol. 46, 1896, pp. 50-57.) It is also reported from Hoffman's quarry, Fisher's Lane and Tacony creek, Frankford, Philadelphia, (E. T. Whery, Journal of the Franklin Institute, Jan. 1908.)

MUSCOVITE. (See mica.)

NICKEL AND COBALT.

These two metallic elements so often occur together that they are here treated under one head.

Cobalt in Pennsylvania has been found in some of the manganese ores as Wad and Psilomelane; as minute crystals a sulp-arsenide at Phoenixville, with the lead minerals, and at Cornwall, Lebanon county. It is not an important substance in this State.

The chief ores of nickel so far as Pennsylvania occurrences go are as follows:

Name.	Composition.	Theoretical Per Cent. Nickel.
Pyrrhotite,	$Fe_{11}S_{12}$,	0-6
Millerite,	NiS.	64.6
Genthite,	$2NiO_2$. $2MgO$. $3SiO_2$. $6H_2O$,	22.46

NICKEL IN PENNSYLVANIA.

The nickel mines in this State are not only of considerable historic importance but for many years the only nickel produced in America came from the mines at Gap, Lancaster county.

This mine was discovered in 1732 and was originally worked as a copper mine but was abandoned because of the small quantity of the production. In, or about, 1863 the mines were reopened as it was discovered that considerable of the metallic sulphide ore was nickel bearing. The mine was operated as a nickel producer from 1863 to 1888, as the only working nickel mine on the North American continent. The product was smelted at Gap to a "nickel-matte" and from there shipped to Camden, New Jersey, where the matte was refined to recover the nickel. In 1902 the mine was again opened for a short time. It was the opinion of the late Mr. Joseph Wharton that as the Gap mine "was worked only to a depth of less than 300 feet.... ......it is reasonably certain that large resources of ore remain there untouched awaiting discovery by the diamond drill followed by modern methods of mining and smelting" (18 Annual Rep. U. S. Geol. Survey, Pt. V, 1897.)

In Report C 3, p. 274, Sec. Geol. Survey are analyses of the Gap ore showing from 1.53 per cent. nickel and cobalt to 4.23 per cent. of same. Copper runs from 1.10 per cent. in these samples to 2.26 per cent. This is a pyrrhotite.

Millerite, nickel sulphide NiS, is found at Gap mine and at times in considerable quantity. The following analysis is by Dr. Genth. (Rep. B. Sec. Geol. Survey.)

Sulphur,	35.14
Nickel,	63.08
Cobalt,	0.58
Iron,	0.40
Copper,	0.87
Ga,	0.28
	100.35

This rather pretty mineral is found in radiating masses of fibrous brass yellow material usually occurring as crusts in thin layers.

Zaratite, a vivid green carbonate of nickel has been found on chrome iron at Texas, Lancaster county. It is not a commercial mineral.

Genthite, a variety of *Garnierite,* is a silicate of magnesium somewhat akin to Serpentine; it at times carries 30 per cent. of oxide of nickel, NiO. It has a yellowish apple green color and rather waxy lustre. It also is found in the chrome localities. It may be worth while to remark that vegetable green stains which have penetrated rocks are frequently mistaken for stains of nickel or copper, and certain iron minerals have a color which may be mistaken for compounds of nickel or copper.

Other localities in the State are known for nickel minerals but they are not of value; these are at Van Arsdale's quarry in Bucks county, at the Lafayette soapstone quarries on the Schuylkill; near McKinney's quarries on the Wissahickon (with chalcopyrite); in Alsace township, near Reading.

OCHER. (See mineral paint.)

ORTHOCLASE. (See feldspar.)

PAINT ORE. (See mineral paint.)

PETROLEUM.[1]

Petroleum has been known so long in this State that references to it's presence may be found in the accounts of the expeditions, such as Burgoyne and others, to Western Pennsylvania before the American Revolution. However this natural oil was not in general use as "coal oil" was made for many years by the distillation of coal. This was an important industry up to the discovery of petroleum in large quantity in this State. There is not space here to give the details of this history, reference may be made to the various reports of the Second Geological Survey.

[1]The developments in the petroleum industry since the time of the Second Geological Survey, have been so extensive, that it is impossible in such a report as the present, to give any details. To treat of the oil and gas industry as it exists today, will require a great amount of work and time. Reference should be made to the reports of the U. S. Geol. Surv., made in co-operation with the State, covering portions of the oil and gas fields, and to reports Nos. 1 and 3, of this Survey. For a brief general review of the subject reference should be had to the report of the Top. and Geol. Surv. Com. for 1906-08.

From the early beginnings the industry has grown to be one of the most important in this State and has been so for many years.

At the present time there are over 50,000 producing oil wells in the State.

These are located as follows:—Allegheny, Beaver, Bradford, Butler, Clarion, Crawford, Elk, Fayette, Forest, Greene, Lawrence, McKean, Mercer, Tioga, Venango, Warren and Washington counties.

Petroleums are usually divided in to these having a parafine base and those having an asphaltum base. Without going into details it may be said that the parafine oils are the most valuable for producing illuminating oils and the gasolines or napthas.

The Pennsylvania oils are predominantly parafine oils.

*GEOLOGIC CORRELATION OF THE PRINCIPAL OIL SANDS OF PENNSYLVANIA.

Formation.	Driller's Name.	Geologist's Name.
Monongahela,	Pittsburg coal,	Pittsburg coal.
Conemaugh,	Murphy sand,	Morgantown sandstone.
	Little Duukard sand,	Saltsburg sandstone.
	Big Dunkard, Hurry-up or Cow Run sand.	Mahoning sandstone.
Allegheny,	Gas sand,	Kittanning, Clarion or Homewood sandstone.
Pottsville,	Salt sand Sixtyfoot,	Connoqueunessing, or Pottsville sandstoue.
Mauch Chunk,	Little lime, Salvation, or Maxton sand.	Greenbrier limestone.
Pocono,	Mountain, or Big Injun sand,	Burgoon saudstone.
	Squaw.	
	Papoose.	
	Butler gas, Butler 30-foot, gas, Salt, Murrysville, or Berea (?) sand.	
	Gantz and Fiftyfoot or Hundredfoot sand.	
Catskill,	Nineveh 30-foot or Thirtyfoot sand.	
	Snee, Blue Monday, or Stray-stray sand.	
	Boulder, Gordon Stray, or Campbell Run (?) sand.	
	Gordon, or Third sand.	
	Fourth sand.	
	Fifth sand.	
	Fifth (McDonald) sand.	
	Bayard, or Sixth sand.	
Chemuug,	Elizabeth sand.	
	Warren first sand (?).	
	Warren second sand (?).	
	Speechley sand.	
	Tiona sand.	
	Bradford First and Second sands.	
	Elk (?) sand.	
	Kane (?) sand.	

*From report of Topographic and Geologic Survey Commission of Penna,, Harrisburg, 1908.

PHOSPHATE MINERALS.

The minerals which carry *phosphoric acid* or its compounds are very numerous as to species, but of these few are of commercial value and of these few only a still more restricted number are found in Pennsylvania. In composition phosphatic minerals range from compounds of metals such as iron, lead, copper, the rare elements such as uranium and cerium; to lime, magnesia, etc. Many of these are of purely scientific interest while others are of very considerable value in commerce and the useful arts.

The mineral phosphates which have been found in this State are as follows:

Apatite. A lime phosphate with fluorine and chlorine. Phosphoric acid=41—42 per cent.

Pyromorphite. A lead phosphate. Phosphoric acid=10—18 per cent.

Vivianite. A phosphate of iron carrying water. Rare; at the old nickel mine at Gap, Lancaster county.

Wavellite. A phosphate of alumina with water.

In addition to the above species are some rare minerals carrying Vanadium and Uranium phosphates. The Uranium minerals are given under that head.

Apatite has been found in Berks, Chester, Montgomery, Delaware, Philadelphia and York counties. There are no commercial workings. Apatite is a mineral somewhat softer than feldspar or steel, occurring in smooth, six-sided, prism-like crystals and showing a variety of colors, blue, green, brown, yellow and white. Apatite in some form is the basis of many phosphate rocks and is found in guano in part.

The following are some of its chief localities in Pennsylvania. In large, rough, blue-green crystals at Leiperville and other gneissic-granitoid rocks near Chester, Pa., and Wilmington, Del.; at several quarries in West Philadelphia, at 69th and Arch and Race streets; at McKinney's quarry, Germantown, and at Frankford in the same sort of rock as at West Philadelphia; in Chester county at Penn's Meeting house, London Grove township; with Magnetite at the old Jones Mine, Berks county; in the soapstone quarries at Lafayette, Montgomery county; at the old limestone quarry at Van Arsdale's, Bucks county. Apatite in small srystals, almost microscopic, has been found in the altered shales adjacent to trap at York Haven, York county.

Wavellite, with Apatite, is the basis of most of the rock phosphates. It is mined in the State at Moores' Mill, four miles west of Mt. Holly Springs, Cumberland county; and has been reported as occurring in Perry county. Large mases of Wavellite with hydrated iron ores

occur near White Horse Station "Steamboat"; East Whiteland township, Chester county. It was found also in the Limonite deposits of Lancaster county and probably in others of the old ore banks.

The following analysis of the White Horse sample is given in Genth's Rep. B. 2nd Geol. Survey of Penna.

Phosphoric acid,	34.68
Alumina,	36.67
Water,	28.29
Limonite,	0.22
Ferric oxide,	0.00
Fluorine,	trace
	99.86

Wavellite generally is found in very small srystals, in globular or lumpy masess with a fine radiating structure, or else in stalactitic masses which are sometimes smooth and at other times rough. The colors are pale blues and greens; grays, yellows or brown when iron is present. It occurs also in earthy forms in clays and shales and its presence is not always to be detected without a chemical analysis; such occurrences have been reported at the Trimble iron mine, Chester county.

Wavellite is used as a source of phosphoric acid for fertilizing purposes; and as a source of alum.

It was formerly mined at White Horse.

POTASH AND SALINE MINERALS; BITTERNS.

As the subject of potash and the search for potash sources is one of great interest and value, and as there are several possible sources of potash in this State, the following general remarks on the subject are quoted from a report by W. C. Phalen of the U. S. Geological Survey.

"The metallic element *Potassium*, represented by the symbol K, is the basis of all potash salts, but the combination of potassium with oxygen, represented by the symbol K_2O, has been generally adopted as the standard for measuring the potash value of the various kinds of potash salts. As a matter of fact, K_2O does not exist commercially, being merely used as a convenient standard. The following table shows the "potash" or K_2O in the several commercial potash salts and minerals.

Name.	Symbol.	Percentage of potassium (K).	Chemical equivalent in terms of "potash" (K_2O).
Element			
Potassium,	K,	100	....
Potassium salts or "potash" salts			
Potassium chloride[a] (mineral sylvite),	KCl,	52	63
Potassium muriate (same as chloride),			
Potassium sulphate,	K_2SO_4,	45	54
Potassium nitrate (saltpeter),	KNO_3,	39	47
Potassium hydrate or caustic potash,	KOH,	70	84
Potassium carbonate,	K_2CO_3,	57	68
Potassium cyanide,	KCN,	60	72
Stassfurt Minerals			
Carnallite,	$KMgCl_3.6H_2O$,	14	17
Kainite,	$MgSO_4.KCl.3H_2O$,	16	19
Sylvite (potassium chloride),	KCl,	52	63

[a] Potassium chloride is in the trade known by the chemically obsolete term "muriate of potash."

With these values in mind it is therefore easy to determine the real potash content of any potash-bearing mineral. Thus a fertilizer carrying 60 per cent. of sulphate of potash would contain 32.40 per cent. of "potash," or K_2O. If pine wood ashes were guaranteed to carry 13 per cent. of potassium carbonate, they would as a matter of fact contain only 9 per cent. of K_2O. Again, a compound carrying 90 per cent. of sulphate of potash would contain but 48.6 per cent. of K_2O, while another compound carrying 80 per cent. of chloride of potash (or muriate of potash) would be equivalent to 50.4 per cent. of K_2O.

Potassium carbonate was for a long time the best-known potash salt, being the residue from boiling lye from wood ashes in iron pots, whence the name potash."

The chief minerals which carry potash are, first, certain compounds known as silicates, that is compounds in which the element silicon acts as an acid to hold certain metallic or basic elements such as potash, soda, lime, etc. in chemical union. Of these silicate minerals the chief potash ones are feldspar of the Orthoclase or Microcline variety, muscovite (white or potash) mica, volcanic or igneous rocks such as rhyolite, and some other silicate minerals in which the potash content is either too small to be of use or is not in a form which may easily be obtained. In fact the mica and feldspar are not at present commercial sources of potash as the cost of extraction is too high. In addition to the above are some potassium chlorides, sulphates, etc., such as alunite, a sulphate of alumina and potash; sylvite, a potassium chloride, and other analageous minerals.

Moreover, of late attention has been called to the refuse brine from salt wells, waters carrying mineral salt from oil and gas wells, etc. Brines are not at this time under serious investigation in Pennsylvania. Granitic and rhyolite rocks are found in the South Mountain and are also not now in use as sources of potash, and may never be used unless their potash content should be large enough to extract at a profit. The mica schists and the gneisses and granite rocks of the south-eastern counties of the State contain immense amounts of potash locked up in combination with silica and alumina. In addition it may be said that much orthoclase feldspar, now rejected for porcelain making because of iron present, may perhaps be available for potash as soon as a cheap method of extraction is discovered.

(See also under Salt and Salines for further information as to Potash.)

SALT.

SALT BRINES AND OTHER SALINE MATERIAL.

Under the head of potash reference was made to "brines." These are natural waters in which are found enough quantities of common salt, (sodium chloride), and other saline matter to be of commercial value. The elements found in these brines include, first, alkaline and metallic elements, such as potash, soda, magnesia, lime, lithia, iron,

alumina, etc., and also the elements of an acid character and known to chemistry as the *halogen* or salt forming group. These latter, with their names and chemical symbols are:

Fluorine,	Fl.
Chlorine,	Cl.
Bromine,	Br.
Iodine,	I.

Common salt, for example, is a chemical union between the element chlorine and the element sodium (Natron) having the chemical formula. NaCl. While this is the most valuable of these compounds there are others which are exceedingly useful and even necessary in civilized life.

Bitterns are the residual brines left in the recovery of common salt from these natural waters. These "bitterns" contain potash compounds and are now under careful study by the U. S. Geological Survey as possible sources of potash.

OCCURRENCE IN PENNSYLVANIA.

It may not be generally known that Pennsylvania has been a salt producing State for many years back, though at present the amount produced is small. *The Pennsylvania Salt Company* is one of the oldest companies of the kind in the country.

At Saltsburg, Tarentum, Freeport and other localities along the Conemaugh river and on the Kiskiminetas river, saline waters were formerly worked for salt. While these are at present neglected they are very well worth consideration as possible sources of *potash*.

Bromine. Many of the salt waters of western Pennsylvania have rather large percentages of bromine compounds and in fact the first extraction of *bromine* in America was at Freeport in 1846. (H. Ries, "Economic Geology," 1910, p. 171.) At the present time bromine is still produced in this State. Bromides are used in photography, medicines and in chemical industry.

The following analyses are taken from Genth, Rep. B. Sec. Geol. Survey of Penna., p. 26.

ANALYSIS OF SALT WATER.[1]

(The quantities given are in parts per 1,000).

Chloride of sodium,	71.320
Chloride of magnesium,	3 986
Chloride of calcium (lime),	15.726
Bi-carbonate of lime,	0 005
Bi-carbonate of iron,	0 078
	91.115

[1]Water from the neighborhood of Saltsburg.

BITTERN (MOTHER LIQUOR) FROM FREEPORT. QUANTITIES IN PARTS PER 100.

Chloride of potash,	0.128
Chloride of soda,	0.887
Chloride of lime,	24.640
Chloride, bromide and iodide of magnesia,	10.146
	35.791

The magnesium content of 10.146 parts was made up as follows:

Magnesium,	2.5750
Chlorine,	6.8660
Bromine,	0.7010
Iodine,	0.0035
	10.1455

Salt is still produced in commercial amount from Allegheny county.

PSILOMELANE. (See manganese.)

PYRITE AND MARCASITE.

These two minerals are both sulphides of iron, FeS_2. They are used for producing sulphuric acid, the refuse matter after burning is sold under the name of "blue billy" as a mineral paint, and as an iron ore in small part. Pyrite occurs in slates, shales, limestones, in quartz veins, and is common in coal mines. Being of a bright yellow color and having a shine and sparkle it is very often mistaken by the inexperienced for gold. While pyrite occurs in many places in the State in small quantities, it is not a commercial mineral in Pennsylvania. It has been mined in Mercer county, probably from the coal. It occurs sparingly in limestones and in some of the iron ores.

Pyrite is found in lumps or in crusts of square, bright yellow crystals in the coal-mine slates, and is often called "sulphur" by the inexperienced. This is not correct as pyrite is a compound of sulphur and iron. It is sometimes polished and set as an ornamental stone. Pyrite has been found in very beautiful crystalline forms at French cree', Chester county, where it occurs with magnetic iron oxide and chalcopyrite. This locality, while of great scientific interest, is not one of commercial importance.

Pyrrhotite, a sulphide of iron having the composition of $Fe_{11}S_{12}$ is also used as a source of sulphuric acid. This mineral is of a dark bronze, brown color and is somewhat magnetic. Its occurrences in the State have been mentioned under the head of nickel minerals as pyrrhotite. It is chiefly valuable as an ore of nickel. Pyrrhotite is not as frequent a mineral as pyrite in its occurrences.

ANALYSIS OF PYRITE "FROM THE COAL MEASURES."[1]

Bisulphide of iron,	96.161
Bisulphide of copper,	Trace
Alumina,	00.653
Lime,	0.450
Magnesia,	0.140
Silica,	0.680
Undetermined,	1.916
	100.000

[1]Analysis by J. M. Stimson Sec. Geol. Survey, Rept. M2, p. 374.

The two following analyses by McCreath show the paint produced from the above pyrite after roasting by the Oriental Paint Co., Jamestown, Pa. Analysis No. 1 shows the unwashed product; No. 2, the same after washing to remove the sulphuric acid which would impair the paint if allowed to remain.

ANALYSIS OF "BLUE BILLY."[1]

Sesquioxide of iron, Fe_2O_3, ...	66.143	77.143
Protoxide of iron, FeO, ...	6.300	5.142
Bisulphate of iron, FeS_2, ...	0.415	0.405
Alumina, Al_2O_3, ...	0.697	0.543
Lime, CaO, ...	0.160	0.160
Magnesia, MgO, ...	0.100	0.100
Sulphuric acid, SO_3, ...	13.110	7.334
Silica, SiO_2, ...	3.880	3.980
Water and carbon matter, ...	9.195	5.193
	100.00	100.00

PYROLUSITE. (See manganese.)

PYROMORPHITE. (See lead.)

QUARTZ.

Rock crystal; Flint, SiO_2, silicon dioxide. This is the most abundant of all known minerals; it varies widely in its form, occurring as sand, sandstone, quartzite, vein quartz, flint, chert; as gem like rock crystal and amethyst; it is also an essential part of granite and in addition is found largely in schists and in veins in granite where it is nearly always associated with feldspar, mica and garnet. Some petrified wood is quartz or flint.

Quartz in the form of rock crystal is found in six-sided crystals with pyramidal ends. These crystal forms vary in length so as to be at times very much longer than thick. At other times they are short and stumpy. They are possessed of a high, at times a very brilliant, lustre and when the faces (sides) of these crystals are smooth and the specimen free from iron or other stains they are sometimes mistaken for diamonds.

Quartz is a very hard mineral, much harder than steel, breaks with no definite direction and when in pure, massive state often has the appearance of white ice or snow. In rock crystal form it may be clear, transparent and colorless; in other specimens the color varies from yellows to browns and pink; amethyst is a purple-blue variety. Iron stains change the color and are exceedingly common. The massive forms such as sandstone, and quartzite are described elsewhere in this report.

Quartz is of wide occurrence and usefulness in its various states. As rock masses or otherwise it is used in various forms of structural work as sandstone and sand, as described under those heads. In addition it is used as material for glass making, as foundry and other sands; it is employed as an abrasive, for sandpaper and scouring and

[1]Sec. Geol. Survey of Penna., Rept. M2, p. 374.

polishing material in soaps and other substances; it is used in wood filler and paints, for lining acid steel furnaces and puddle furnaces, it is used also as a flux in extraction of copper ores, as material for making ferrosilicon; as material in sand-lime brick and other brick and clay products and in mortar. Quartz in the form of sand is introduced into certain sorts of clays used for pottery to decrease the shrinkage of the ware in burning. Owing to its insoluble character it is employed as a means of filtering the strong mineral acids in acid towers, for this purpose the quartz rock must be free of iron and other soluble mineral matter.

Of late years quartz has come into wide use as a material of which to make chemical apparatus which is known as "fused quartz ware." The finest quality of this ware is made from very carefully hand-picked pure rock crystal known as "Brazil Pebble" from the fact that the old diamond washings from Brazil yielded such material. Of late years quartz has been treated in the electric furnace to obtain chemically pure silicon which in turn is used to reduce the oxides of tungsten, chromium, etc., to metallic form; this the silicon does because of its strong affinity for oxygen, absorbing it and going back to silica again.

In short, quartz is used for so many different purposes that it is one of the most useful and valuable of all known minerals.

Its Occurrence in Pennsylvania is widespread as sands, and sandstones, as glass making material, ganister and so forth. These are described elsewhere.

Quartz crystals have been found loose in the soil and ploughed up or washed out by the rain in some of the old limestones of the eastern part of the State.

The following are some of the many localities where crystals have been found: These are in part mentioned in Genth's report on the mineralogy of the State and others are taken from specimens in various collections, public and private.

Berks county near Kutztown; and Reading; Chester county; at Poorhouse quarry, West Bradford township; at Brintons and other quarries in East Bradford township; at Pennsbury occur crystals enclosed in mica; Delaware county at many places in Concord, Marple and other townships; in the serpentine barrens quartz in interesting masses, often with groups of small crystals, is found where it has weathered out of the serpentine.

In the Saucon Valley, Lehigh county, occur interesting forms of quartz; in Mifflin county in the limestone soils of Kishacoquillas Valley crystals of a very long prismatic shape have been found since the first settlement of the valley and are still to be picked up, though not as common as formerly; in Monroe county at Stroudsburg (gem quality), Broad Mountain, Shamokin, Cherry Valley, Poconac Val-

ley; in Montgomery county at London Grove, King of Prussia, Phoenixville and many other places; in the counties of Lancaster and York, crystals have been found frequently, in Lancaster county at Kintzers, Pequea and New Holland; in York county crystals were formerly gathered by the farmers and sold to flint mills around the city of York. Crystals may still be had in the quartzite hills about York and in some of the beds of the small streams, as Trout Run; in Northampton county at Nazareth occur large and beautiful crystals.

Amethyst is a variety of quartz of blue-violet color much prized as gem stones. Some really magnificent specimens of Amethyst have been found in Pennsylvania from very small crystals up to clusters weighing many pounds. Individual crystals weighing seven pounds or more have been found in upper Providence, Lower Providence, Aston, Concord, Marple and Middletown townships, as at Duttons Mills; in Chester county equally fine ones have been found as at Sadsbury Village, in East Bradford township and elsewhere; in Adams county at New Salem; slightly tinted crystals have been found and are still obtainable in the South Mountain near Ortanna and elsewhere.

Smoky Quartz is a dark smoky gray to black form often very attractive when cut.

Smoky quartz in very fine crystals is found at approximately the same localities as mentioned under Amethyst.

RADIUM, RADIUM ORE. (See under uranium.)

RUTILE. (See titanium minerals.)

SALT. (See potash and salines.)

SAND, SANDSTONES. (See Silica.)

SERPENTINE.

Serpentine is a silicate of magnesium with water, occurring both as mineral and in rock masses. It has in its purest varieties a semi-transparent quality which places it among the more valuable of ornamental stones; *precious* or *noble serpentine* has a fine oily or waxy lustre, possesses a rich green color, pale or dark, and may be polished to a very high degree. Other forms of the mineral serpentine are used as a substitute for the precious stone *jade*. Chrysotile is a fibrous form of serpentine popularly called asbestos and used as such.

Rock masses of serpentine are among the frequent forms; these are not generally pure but carry dolomite; magnesite, calcite, quartz, and are not infrequently stained by oxides of iron and chromium, producing a great variety of very beautiful colors. These rock masses of serpentine when cut into pillars or columns and when dressed into slabs or blocks are known as serpentine-marble. *Verde antique*, known also as *ophicalcite*, is a mottled form of such marble showing rich, rather spotted contrasts of color. It has been referred to under marbles.

Serpentine of all sorts is a product of chemical and physical alteration of some other minerals or rocks and is to be looked for in consequence in rather restricted areas. In Pennsylvania it is found along the Great Valley, in masses among the crystalline limestones, where it has most probably been formed by the chemical alteration of impure, silica-bearing dolomite limestone. In Lehigh and Northampton counties occur some of the more valuable forms, such as noble serpentine and verde antique. Serpentine is distributed through an area from Northampton county diagonally across the State to the Maryland line from the Susquehanna River to the Delaware, along the State line, occur large masses of serpentine. The chief localities are in the counties of Northampton, Lehigh, Berks, Lancaster, York, Chester, Delaware; it occurs also in Lebanon, Montgomery and may perhaps be found in some of the altered limestones in Dauphin, Adams and Franklin counties, though not reported from these last.

It is quarried at Easton, along with talc, at some 15 or more localities in that district; it has been quarried in the past in a number of localities in Chester and Delaware counties where the stone for houses in Philadelphia was obtained.

SERPENTINE AS BUILDING STONE.

The merits and demerits of serpentine rock for outside use have been somewhat widely discussed with the expression of rather conflicting views and the citation of equally conflicting evidence. The reason for this state of things is not at first sight clear. Serpentine was used as early as Colonial days for exterior building in the State and some of these old houses are still in an excellent state of preservation and show little atmospheric decomposition; on the other hand some houses built in Philadelphia in recent years are in a very advanced stage of softening and decomposition so far as the serpentine is concerned. This difference in behavior is not so much due to variation in the rock as to variation in the condition of the atmosphere. Serpentine being chiefly of a magnesian nature is easily affected by certain sorts of acid vapors in the air, such as sulphurous ones. These sulphurous vapors are not especially noticeable in the rural districts but are very pronounced in cities where smoke and vapors from chemical and other manufacturing plants are very common. Magnesian rocks are especially susceptible to such vapors as magnesium sulphate is an exceedingly soluble compound. Moreover, serpentine carries considerable iron in a low state of oxidation (as much as 12-14 per cent. at times) this under exposure to the atmosphere changes to a higher state of oxidation, and if this change is accompanied by a simultaneous affecting of the magnesium, decomposition of the rock is almost certain to follow.

Some of the buildings of the University of Pennsylvania near the Schuylkill River, faced with serpentine, afford very interesting illustrations of these facts; they were erected in 1871-1872 and are now, especially on the southern and eastern sides, (the sides of greatest wind exposure) very seriously affected. To the south of the University are large manufacturing plants, oil refineries, and railroad lines; these all, through smoke vapors and fumes from the refineries, produce considerable quantities of sulphur gases which have eaten into the serpentine facings of buildings; a further illustration, if any are needed, to show the great necessity of elimination of smoke and acid vapors from the atmosphere.

In Berks and Chester counties are serpentine houses which are over a century old and are still in a fresh and sound state; this is due to the fact that the air, to a great extent, is free of smoke, fumes and destructive vapors.

The facts then seem to be that under favorable atmospheric conditions serpentine is not only an exceedingly beautiful exterior stone but is durable. Under the conditions of atmosphere in practically all of our cities its use is at least of doubtful expediency for general exterior building purposes; though even in the weathered form it is possessed of considerable attraction and beauty. Its use for interior decoration is not affected by the above factors and for these uses it will always be of great value.

Other buildings in Philadelphia constructed in part or entirely of serpentine, exteriorly, are scattered generally over the city. Among the more prominent ones were the old buildings of the Academy of Natural Sciences at Logan Square. These were in a very bad condition from the decomposition of the serpentine, and have been refaced with other material; the building at the southwest corner, facing north, was very much affected at the northeast corner, doubtless due to railroad smoke, which carries much sulphur vapor, as all coal smoke does. The edifice of St. James Church, at Twenty-second and Walnut streets, also of serpentine, is a further instance of the injury done by smoke; it also has been redressed to remove the decomposed surface.

SHALES.

Shales are clay rocks which occur in beds or natural layers known as *strata* and are the result of the depositing of clay materials in water. These water deposits are subsequently hardened and compacted into rock which usually has to be ground to bring it into a powdery condition. Shales are not as a class as pure as some other clay materials and show graduations into limestone on the one hand and into sandstones on the other. The following table shows a composite anlysis of 78 shales made in the laboratory of the U. S. Geological Survey at Washington.[1]

[1]Bull. U. S. Geol. Surv. 491, p. 28. The Data of Geochemistry.

SiO_2 silica,	58.38
Al_2O_3 alumina,	15.47
Fe_2O_3 ferric oxide,	4.03
FeO ferrous oxide,	2.46
MgO,	2.45
CaO,	3.12
Na_2O,	3.12
K_2O,	3.25
H_2O 110°,	1.34
H_2O +110°,	3.68
TiO_2,	0.65
CO_2,	2.64
P_2O_5,	0.17
S,	......
SO_3,	0.65
Cl,	......
BaO,	0.05
SiO,	none
MnO,	trace
Li_2O,	trace
Carbon (organic),	0.81
	100.46

The average composition of shale in terms of the minerals present has also been expressed by the same authority as the previous anlysis. This is as follows:—

Quartz (total free silica),	22.3
Feldspars,	30.0
Clay,	25.0
Limonite,	5.6
Carbonates,	5.7
Other minerals,	11.4
	100.00

Slates are shales which have been subjected to such severe pressure and chemical change that the physical characters of clay are lost. They do not become plastic upon grinding and are of little or no use in clay working.

Shales to be used in clay working are artificially disintegrated or crushed, which is usually done dry. The shale may have to be crushed in jaw-crushers and afterwards ground in pans to a powdery condition. Shales are used for making the various types of vitrified ware, such as terra-cotta and brick, "shale brick" being a common type.

Shales in Pennsylvania are of wide occurrence and are found in both the older and later geological formations. The Cambrian shales such as those found in the vicinity of York are used for shale brick. The shales from the Clinton, Niagara, and Carboniferous are also used for this purpose. The shales from the "red-beds" of the Triassic are not used as commonly as are those of the other formations.

"Ochers" are often made from shale; see mineral paint.

Shales are of practically unlimited quantity in the State though not always of value for brick or tile; most of the shale in present use for this purpose is from the *Conemaugh* formation of the **carboniferous.**

ANALYSIS OF BRICK SHALES FROM CONEMAUGH FORMATION EAST OF JOHNSTOWN, PA.[1]

		(1)	(2)
	Silica,	51.32	64.29
	Alumina,	24.39	17.95
Fluxing Impurities	Fe_2O_3,	6.94	5.74
	Mno	.14	trace
	MgO,	1.93	1.30
	CaO,	.70	.46
	K_2O,	1.09	1.80
	Na_2O,	.23	.35
	H_2O 100°,	.92	.95
	Ignition loss,	11.32	5.44
	SO_3,	trace	trace
		100.21	99.92

Rational Analyses.

Free silica,	10.09	28.54
Clay subs.,	81.51	57.85
Feldspar sub.,	8.40	13.61

Shale brick. It has been found by experience that some clays are not suitable for brick making when used alone as they do not give sufficient strengthening qualities to the brick. In consequence of this fact ground shales are added to the mix or the ground shales may be used with practically no clay admixture. Analyses of such shales and clays are given here from the Ohio Geological Survey.

ANALYSES OF SHALE AND CLAY, *a*.

	1.	2.	3.	4.	5.
SiO_2 (total),	58.20	49.30	57.45	55.60	57.15
Al_2O_3,	22.47	24.00	21.06	24.34	20.26
Fe_2O_3,	5.63	8.40	7.54	6.11	7.54
CaO,	.62	.56	.29	.43	.90
MgO,	.98	1.60	1.22	.77	1.62
K_2O,	3.08	3.91	3.27	3.00	3.05
Na_2O,	.42	.19	.39	.09	.58
H_2O (combined),	6.15	9.40	5.90	6.75	5.50
H_2O (uncombined),	1.65	1.20	1.90	2.65	2.70
	99.20	98.56	99.02	99.74	99.30

*a*Orton, Geol. Survey Ohio, vol. 7, pt. 1, 1893, pp. 133, 134.

1. Shales and fire clays mixed, from the T. B. Townsend Brick Company, Zanesville, Ohio; Freeport shales and Kittanning fire clay. N. W. Lord, analyst.
2. Shale from Waynesburg Brick and Clay Manufacturing Company; Middle Kittanning (Darlington?) horizon. N W. Lord, analyst.
3. Shale from the Ohio Paving Company, Columbus, Ohio. mined at Darlington, Ohio; Lower Kittanning horizon. Average sample. N. W. Lord, analyst.
4. Shale and fire-clay mixture, from the A. O. Jones Company, Zanesville, Ohio; Kittanning horizon. N. W. Lord, analyst.
5. Shales used by Bucyrus Brick and Terra Cotta Company, mined at Glouster, Ohio; horizon of Cambridge (near Ames) limestone. Average sample. N. W. Lord, analyst.

SIDERITE. (See iron ores.)

SILICA. SAND. SANDSTONE.

Silica, silicon dioxide, SiO_2, occurs as one of the most wide-spread rock or mineral forms in nature; as sandstone, as flint, as quartz, and in chemical union with hosts of other mineral and rock masses it is practically universal in its occurrence.

[1]U. S. Geol. Surv. Folio 174, Washington, 1910, p. 14.

Sand and *sandstone* are rocks made up of small pieces of quartz, which have generally undergone a long continued natural grinding and sorting by running water. While most sandstone is made up essentially of these quartz grains, other minerals occur such as mica, or more seldom, feldspar, with a further transition on the one hand to sandy limestone and on the other to sandy shale.

Sandstone is held together naturally by a binding material or cement. This is frequently some of the oxide compounds of iron, or it may be silica itself or even calcite. *Sand,* as generally spoken of, means the loose sand grains or it may mean the sand rock crushed to a fine condition; standard sand as specified by the*American Society for Testing Materials* must be at least 95 per cent. pure silica (SiO_2) and shall pass through a "No. 4" sieve.

Gravel is a loose mixture of sand grains and pebbles. This is common along water courses and in this State is often found in the northern tier of counties above and along the streams below the glacial drift line.

Sand and sandstones are used for many purposes; as abrasives, as sand in mortars and cements and concrete, as filter sand, as foundry sand, as material for glass making and pottery, porcelain, tile and brick; as structural material of other sorts such as building stone.

Quartzite is a term applied by geologists to rock which in its first origin was a sandstone, sometimes a gravel rock (conglomerate), which has undergone such a change in structure due to the filling of the pores by secondary quartz that in large measures the original sand grains are no longer apparent and the rock mass appears to be solid quartz. These quartzites are found in the southeastern portion of the State among the older rock formations.

On account of the varieties in sand rock and because of the diversity of use, the following names may be mentioned as being in common use.

Arkose, a sandstone made up of fragments of granite, that is to say, a rock composed of much free quartz with mica and feldspar. This is often called "granite-sandstone." This rock is found in the Triasic beds in Montgomery, Bucks and York counties and elsewhere. It possesses the very valuable quality of hardening upon exposure after quarrying and is valuable for certain sorts of structural work.

Blue stone is a term not always definitely used; properly speaking, it is a fine grained, compact, dark blue sandstone with some clay substance. It is often a flagstone and is also used for ballast or road metal, though not especially good for this use. The term blue stone is also applied at times to blue limestone.

The typical *blue stone* comes from Pike, Wayne or other northeastern counties. Its production has been reported from Adams,

Bradford, Bucks, Clinton, Fayette, Greene, Lackawanna, Luzerne, Lycoming, McKean, Pike, Potter, Schuylkill, Susquehanna, Wayne, Westmoreland and Wyoming counties, though whether this is always typical blue stone may well be doubted, as different rocks, as stated, are sold as blue stone.

Brownstone originally meant a brown or reddish brown sandstone from the Triassic formation. Its typical locality in this State is at or near Hummelstown where it has been quarried in the past in enormous quantity as a building stone known widely as "Pennsylvania Brownstone." Of late years it has not been used as much as formerly. It is a very beautiful building stone and when properly selected and set up in the building will last indefinitely, as many old houses show. It sometimes carries a considerable quantity of shale which, of course, is not good for building purposes.

Of late years a considerable range of other sandstones which are brownish or reddish have been called "brownstone," so that now the term has not always a definite reference to any particular rock or any particular location. The brown color is, of course, due to oxides of iron which is one reason for the stone's durability, as the iron is already in a thoroughly oxidized condition and will not stain or cause the rock to crumble. Of late years the Hummelstown brownstone has been used for making "sand-lime" brick.

The following analyses show its general character.

ANALYSES OF BROWN STONE.[1]

	A	B
SiO_2, silica,	88.13	82.34
Al_2O_3, alumina,	5.81	11.46
Fe_2O_3, ferric oxide,	1.77	1.07
FeO, ferrous oxide,	0.31	......
CaO, lime,	0.20	0.27
MgO, magnesia,	0.53	0.19
MnO_2, manganese oxide,	......	.07
K_2O, potash.	2.63	.17
Na_2O, soda,	0.06	3.76
H_2O, water,	0.49	.80
	99.93	100.13

Analysis "A" is from Hummelstown; "B" is from Newtown, Bucks county.

While the Triassic rocks in Pennsylvania occur in quite a large area they are not always of value as brownstone producers; the chief localities are in a general south-western direction from Trenton, N. J., through Bucks, Berks, Montgomery, Chester, Lebanon, Dauphin, York, Adams and other adjacent counties.

The Mauch Chunk, the Medina, Catskill, Pocono, and other sandstones are sometimes brown or red enough to be classed as brownstone.

'*Brownstone*" is quarried at Birdsboro and Mohrsville, Berks Co.; Grenoble Station, Lumberville, Neshaminy, Newtown and Yardley,

[1] T. C. Hopkins, Annual Rep. of Penna. State College, 1896.

Bucks Co.; Phoenixville and Valley Forge, Chester Co.; Hummelstown, Dauphin Co.; Mount Gretna and Schafferstown, Lebanon Co.; Morristown, Port Kennedy and Fort Washington, Montgomery Co.

Formerly quarried at Middletown, Dauphin Co.; and Goldsboro (Etters), York Co.

Some of this is not true brownstone; the stone from Lumberville is usually grey or pink in color, and there are other localities where true brownstone is not quarried, though the product is sold as such. Most brownstone is *arkose,* which is one reason indeed for its' value, as arkose, though easily quarried, hardens very materially on drying out on exposure. To obtain the best results from brownstone it should be cut and dressed to the form in which it is intended to be used before being allowed to dry out.

The Trias brownstone is obtained generally from the beds known as the *Norristown* of B. S. Lyman, (Sec. Geol. Sur.), or as the *Stockton* of the N. J. Geol. Survey.

Flagstone. This is a sandstone generally, though flagstones are sometimes made of limestones of a shaly character. The chief and useful feature is the fact of the rock being in flat, thin, easily separated layers, which are suitable for pavement use. Flagstones from the limestone members above the Pittsburgh coal are in common use in Brownsville, California, Monongahela and other towns along the Monongahela river. These flagstones are often sandy and clay bearing and show at times very beautiful ripple marks.

Freestone. This is a form of sandstone which splits freely and dresses easily in almost any form desired.

Mill stones, grindstones, whetstones and similar stones are usually made from sandstone.

Ganister is a sandstone used for refractory brick, and resembles quartzite in appearance; it has generally a grey color. Ganister has a less pronounced granulation than most sandstone and is more firm and compact.

It is mined for silica brick at Pattonsville, Bedford Co., McKee Gap and Point View, Blair Co., and Water Street Gap, Huntingdon Co.

[1]ANALYSES OF GANISTER FROM CANOE MOUNTAIN, POINT VIEW, PA.

[Isaac Reese & Sons Company, Analyst.]

	1.	2.	3.	4.
Silica [SiO_2],	97.90	97.98	97.30	98.65
[Iron and alumina] (Fe_2O_3, Al [Al_2O_3]),	.90	.95	1.20	.30
Lime [CaO],	.40	.25	.30	.25
Magnesia [MgO],	.36	.29	.30	.30
Loss on ignition,	.40	.50	.85	.45
	99.96	99.97	99.95	99.95

[1]Charles Butts, U. S. Geol. Surv. Bull. 380.

ANALYSES OF GANISTER FROM QUARRIES AT POINT VIEW, PA.

	1.	2.	3.
[Silica] (SiO_2),	99.10	98.15	98.20
Fe and Al [Iron and alumina (Fe_2O_3, Al_2O_3)],	.60	1.20	1.35
Lime [CaO],	None.	None.	None.
Magnesia [MgO],	Trace.	Trace.	Trace.
Loss on ignition,	.25	.20	.50

ANALYSIS OF GANISTER FROM PATTONSVILLE, BEDFORD COUNTY, PA.

[E. F. Wood, Analyst.]

[Silica] (SiO_2)	98.00
Alumina [Al_2O_3],	1.10
Oxide of iron [Fe_2O_3],	.85
Combined water,	.10

ANALYSIS OF GANISTER FROM WATER STREET GAP, HUNTINGDON COUNTY, PA.

[S. A. Ford, Edgar Thompson Steel Works, Braddock, Pa., Analyst.]

Silica (SiO_2),	97.640
Oxide of iron [Fe_2O_3],	.652
Alumina [Al_2O_3],	.825
Lime [CaO],	.310
Magnesia [MgO],	.140
Loss on ignition,	.460

The specific gravity of ganister ranges from 2.46 to 2.58.

The composition of silica brick as made from Blair County ganister is shown below.

COMPOSITION OF SILICA BRICK MADE FROM GANISTER IN BLAIR COUNTY, PA.[1]

	1.	2.
Silica,	96.06	95.06
Oxide of iron,	.535	1.21
Oxide of manganese,	.04	....
Alumina,	.935	1.79
Lime,	1.45	1.79
Magnesia,	.526	Trace.
Potash,	.146	....
Soda,	.045	....

Other localities for ganister in Pennsylvania are to be looked for in the mountain counties of central Pennsylvania and in the "quartzites" of the York-Lancaster district, and in general in the southeastern part of the State where quartzite out crops.

In the Fayette district ganister has been quarried in a number of places. The general requirements of ganister rock are to be seen from the Blair county analyses.

[1]Charles Butts, U. S. Geol. Surv. Bull. 380.

Molding sand (foundry sand) occurs as follows: Pittsburgh, Allegheny, Co.; Koppel, Beaver Co.; Berne and Hamburgh, Berks Co.; Hollidaysburg, Blair Co.; Tullytown, Bucks Co.; Cabot, Butler, Co.; Ashfield and Bowmanstown, Carbon Co.; Falls Creek, Clearfield Co.; Cattawissa, Mifflinville and Rupert, Columbia Co.; Harrisburg, Dauphin Co.; Ridgeway, Elk Co.; Erie and Fairview, Erie Co.; Dunbar, West Masontown, Perryopolis and Republic, Fayette Co.; Waynesboro, Franklin Co.; Mapleton Depot and Mill Creek, Huntingdon Co.; Marietta, Beartown, and elsewhere, Lancaster Co.; Moravia and New Castle, Lawrence Co.; Cementon, Lehigh Co.; Linden and Nisbet, Lycoming Co.; Burnham and Lewistown, Mifflin Co.; Edge Hill and Wm. Penn, Montgomery Co.; South Bethlehem and Freemansburg, Northampton Co.; Milton and Riverside, Northumberland Co.; Newport, Perry Co.; Philadelphia, Philadelphia Co.; Rowena, Somerset Co.; Lopez, Sullivan Co.; Unita and South Oil City, Venango Co.; New Stanton, Westmoreland Co.; near Weiglestown, York Co.

It is hardly possible to mention all the localities in the State but sandstone is quarried in the following counties; Allegheny, Armstrong Beaver, Bedford, Berks, Blair, Bradford, Bucks, Butler, Cambria, Carbon, Chester, Clearfield, Clinton, Columbia, Crawford, Delaware, Dauphin, Elk, Forest, Fayette, Greene, Huntingdon, Indiana, Jefferson, Lackawanna, Lancaster, Lehigh, Luzerne, Lawrence, Lebanon, Lycoming, McKean, Mercer, Monroe, Montgomery, Northumberland, Potter, Somerset, Susquehanna, Washington, Westmoreland. These localities represent a wide series of sandstones from practically all the great sandstone formations, from the carboniferous age down to the older Cambrian.

PRODUCTION OF SAND AND GRAVEL.

These materials are produced in such great abundance and of such wide-spread occurrence that the localities may scarcely be given. Practically all the rivers and streams of larger size yield these materials. The demand for such material in Pennsylvania for structural work and for many other purposes is very great and the supply commands a high price per ton, probably larger than in any other State. This is due to the superior quality of the material produced and the very large demand.

Owing to the great value of the material and the importance of river sands in the trade the following observations on the sands of some Pennsylvania rivers are quoted from Bull. 430, U. S. Geol. Survey, pp. 388ff. E. W. Shaw.

"The area includes Beaver, Allegheny, and Armstrong counties. The gravel and sand are found on terraces and in the river bottoms and are of two distinct types, glacial and nonglacial. The greatest amount of gravel digging has been done in Allegheny county.

"The sand and gravel resources of several near-by counties are almost as great as those of Allegheny county. Valuable deposits are found along the Allegheny and Ohio, on terraces and in the bottom lands, a large output being taken by dredges from the river beds.

"This gravel is the most valuable in the region and extends from approximately 100 feet above low water to 50 feet below. The present thickness ranges up to about 130 feet, and probably the original thickness was slightly greater.

"The lower reaches of the Monongahela and other tributary streams flow over beds of gravel which, except for their slight weathering, closely resemble the nonglacial high-terrace deposits. Near Pittsburgh the base of this late nonglacial gravel lies about 45 to 50 feet below and the upper limit 100 feet above low water. Upstream the deposit rises and thins, and at the West Virginia line it has the thinness and other characters of an ordinary flood-plain deposit. The Monongahela does not flow on a bed-rock channel anywhere within the State of Pennsylvania. At many places the river has swung into the side of the valley, leaving the deposit on the opposite side, and has laid consolidated rock bare, but nowhere does hard rock extend across the full width of the river.

"The late nonglacial gravel contains considerable bodies of clean sand and many of these have been worked. The sand differs from the sand of Allegheny river in being round grained. The pebbles are also well rounded. Many of them are rather flat, but few are angular. On the whole, there is much more fine material in this deposit than in the late glacial gravel.

"Some of the Allegheny river sand is usable for *grinding plate glass.* Uniformity of size seems to be an important requirement of sand for this purpose. At Ford City large quantities are used until ground fine and then washed back into the river. However, much of the river sand is not suitable for this work. Certain sands seem to be desirable in purity, size, and angularity of grain and appear to the untrained eye to be like that which is used successfully, but are nevertheless worthless, because they contain here and there coarse grains known to the operators as "lice." The sand of the Allegheny Valley is also used for many other purposes, including molding, building, and filtration. Furnace, engine, and fire sands and other kinds are produced in less quantity. The sand of the Monongahela river is used in grout, for furnace bottoms, in mills, and in street paving.

"The high-terrace deposits of the Monongahela are less valuable than those of the Allegheny and have not been worked extensively. They are, however, used locally in many areas; for example, sand and silt from these terraces were used for the diamond of the new baseball park in Pittsburgh."

SILVER.

Silver like gold has been found within the State but at no known locality in workable amount. In the lead mines at Phoenixville, at the Ecton mine, Montgomery county, at the New Britain mine, Bucks county, at the Pequea mines in Lancaster county, the occurrence is given in Genth's Report B. At the Pequea mine Genth reports that numerous assays of silver-lead ores from here "will yield an average of 250-300 ounces per ton." This was in 1875. Later developments have not shown workings of these deposits though they may be worth a more careful investigation.

A district which has excited much interest and even some occasional excitement as a possible silver producer is that of the copper bearing rock of the South Mountain in Adams and Franklin counties. There seem to be undoubted silver finds there and in some specimens are substantial nuggets of metallic silver with copper. Up to the present, however, no really well paying veins have been reported as being actually worked. These rocks in the South Mountain bear, as is well known among geologists, a very remarkable resemblence to the copper rocks of Lake Superior which carry some silver.

Silver has also been reported from York county and other places but efforts to locate these places definitely have not been successful.

The precautionary remarks under gold may well apply to silver, as really valuable deposits of silver in this State seem very unlikely to be ever found.

SLATE.

Slate is one of the important sources of mineral wealth in Pennsylvania, and while found in few places is quarried in large quantities and sold widely. The chief uses of slate are for covering and protective purposes, such as roofing, and in addition Pennsylvania slate is very highly valued as material for black-boards and of less importance for school slates.

Slate is used for flooring, wainscoting, vats, tiles, sinks, laundry tubs, grave vaults, sanitary ware, refrigerator shelves, flour bins, dough troughs, electrical switchboards, mantels, hearths, well caps, and billiard, laboratory, kitchen, and other table tops, material for these uses is made in the form of slabs from 1 inch to 3 inches or more thick. Refuse slate and slates of various hues are ground to a fine powder and are used as paint fillers, linoleum tints and mortar colors.

Slate is quarried at the following places in the State: Slatington, Lehigh county; Bangor, Chapman, Heimbach and Pen Argyl, Northampton county; Delta and Peach Bottom, York county; in these localities as roofing slate and milling stock. In Carbon county it is quarried for roofing slate only.

There are many other places where slate occurs in the State but not in a form valuable for working. In the coal regions is much rock

of a slaty character and in the older rocks of the South Mountain and adjacent valleys, aside from the localities above, are also many slaty rocks; these, however, do not possess the requisite physical characters of a commercially valuable slate. Color, lustre and slaty cleavage are not always by themselves of sufficient value to classify a rock as a commercially valuable slate. The manner in which the rock stands up under weathering, the number and location of cracks and joints, the occurrence of objectionable flint veins, and lumps of pyrite; the extent and character of the cleavage (splitting) surface, the toughness, and elastic strength and finally the microscopic structure and chemical composition are all of importance in determining the probable value of the rock.

One of the most characteristic features of slate quarrying is the enormous waste by the careless manner in which it is handled, and the equally careless manner in which the waste slate has been dumped over areas of workable rock, thus adding greatly to the cost of quarrying. The introduction of channeling machines and other special mechanical devices has made possible a considerable reduction of waste in the quarrying. This waste is frequently 40-60 per cent. and may even reach 80 per cent. of the total slate quarried, this by bad handling of the large blocks to make "squares." There is always waste from the presence of objectionable mineral, such as sulphide of iron, and flint, and also from the natural imperfections of the rock.

While it is desirable that new deposits of workable slate may be uncovered, it is even more desirable that the deposits we have, both in Pennsylvania and elsewhere, shall be worked by the best mechanical devices so as to utilize as far as possible the slate yet unquarried. There are at present no geological evidences that really workable slate deposits will be discovered in the State outside the present fields. There are slates of an imperfect character in some of the mountain counties of the State, such as Mifflin and also in Adams, Franklin and other regions in the South Mountain. These do not at present show any workable slate formations.

It should be said as a precautionary measure that since slate is an alteration in most cases from shales or clay rocks that many hard shales are often supposed, by those not familiar with the subject, to be valuable as slate.

Kinds of Slate produced in this State. The Lehigh-Northampton district produces a "hard" and a "soft" slate. The upper or northern belt of commercial slate consists of beds of relatively soft slate as at Bangor, East Bangor, Pen Argyl, Slatington, and Heimbach. The lower or southern belt consists of the "hard" slate as at Belfast and Chapman. These hard slates have been used for flagging, posts, steps and other forms in which hardness is a desideratum; this hard slate is usually cut with a diamond saw. Roofing slate in this southern belt is made from selected material.

The soft slates are used for tubs, vats, tiles, fireboards, billiard-tables, black-boards, and similar purposes.

In color these Lehigh-Northampton slates, are nearly all of a dark gray, sometimes a bluish or dark greenish tone and generally of a very fine texture, and may be lustrous or otherwise.

The Peach Bottom slates of York county are of a dark gray color and are used largely for roofing purposes. They are less fissile than the Bangor slates and less flexible but are much tougher.

SMITHSONITE. (See under lead and zinc.)

SPHALERITE. (See under lead and zinc.)

SPHENE. (See titanium.)

STRONTIUM MINERALS.

CELESTITE.

This mineral is a sulphate of strontium, an element akin to barium and calcium (lime). The mineral has often a pale sky-blue color whence the name celestite. It has a high specific gravity and when heated in a blow-pipe flame imparts an intense crimson color to the flame. The nitrate of strontium is used for "red fire."

The chief use of celestite and other strontium compounds is in the refining of beet sugar, since if strontium hydrate, Sr $(OH)_2$, is introduced into the sugar, it forms insoluble sugar compounds which settle out from the molasses; these insoluble "saccharates" are then decomposed by carbonic acid.

Strontium compounds are used in medicine as the salicylate, the bromide, etc.

Celestite has been found sparingly in Pennsylvania, the chief locality being at Bells Mills, Blair county, at the foot of Brush Mountain on the west branch of the Little Juniata river. It occurs in shaly limestone in thin bands(less than an inch thick) of a pale blue fibrous character. This locality was formerly part of Huntingdon county and the original report of the locality was given as from that county.

The mineral was analyzed in 1797 by the celebrated German chemist and mineralogist Klaproth, who found

Strontia (SrO),	42
Sulphuric Acid (SO_3),	58
	100

See Rep. T. Sec. Geol. Survey (p. 128).

Strontianite, the carbonate of Strontium, $SrCO_3$, was found by H. C. Lewis at Mt. Union, Mifflin county.

TALC: SOAPSTONE.

Talc is an hydrous silicate of magnesium. It is a mineral with a pronounced soapy feel, hence the name of soapstone. It often splits apart in layers like mica but is not elastic. It is often found in compact rock form.

Steatite is a rather impure rock form of talc; *pyrophyllite* is a mineral very much like talc in appearance and is often in the trade used as talc, but is anhydrous silicate of aluminum. Talc is put on the market under several forms: as slabs, under the name of soapstone as rough talc, as ground talc. The sawed slabs are used for sinks, wash basins, stove lids, oven floors, table tops, switch boards and other electrical apparatus. Ground talc is used in toilet preparations, in paints, in boiler and steam-pipe coverings, as sizing in paper and cotton fabrics. It is also used illegally as an adulteration for foods, candy, paints, soaps, and in other ways. This is very much to be discouraged, and should be prohibited by law.

OCCURRENCE IN PENNSYLVANIA.

Talc occurs generally wherever the serpentine rocks are found or in association with older crystalline rocks. Talc is an alteration from other magnesian rocks or minerals and is generally not found in granitic areas as these are not magnesian rocks. At present talc is produced commercially from the Lehigh-Northampton district.

This locality is found in a narrow band of serpentine rocks along the southern slope of Chestnut Hill, north of Easton. There are some sixteen localities where the talc is found. The talc and serpentine here are believed to be the result of metamorphism between the old (Pre-Cambrian) limestones and pegmatite veins.

(Details of this locality may be found in Report 5, Topographic and Geologic Survey Commission, 1911.)

Talc also occurs in a rather large deposit on the Schuylkill river at Lafayette, above Philadelphia. This locality was formerly worked but was abandoned some years since, when the quarry caved in; it is now being cleaned out preparatory to reworking. Several varieties are found here. There are other reported localities for talc in Delaware, Chester and other counties. They are not worked commercially.

There are some forms of mica which are apt to be confused with talc; these are, the fine scaly muscovite, known at *sericite,* which has a slippery feel especially if moist; also the green, chlorite, micas which feel slippery and may be separated into smooth and brittle scales, like talc.

Talc is very soft, softer than any of the mica minerals; it's exact chemical formula is $H_2Mg_4\ (Si\ O_3)_4$. When pure it contains 31.70 per cent. magnesia, (MgO.,) this is not extracted commercially.

TITANIUM MINERALS.

These are chiefly rutile, TiO_2; titanite or sphene, a silico-titanate of lime; and titaniferous hematite or titaniferous magnetite. Titanium compounds, except sphene, are used for special alloys such as ferrotitanium, of use in the steel industry, and rutile is used for making enamels, glazes and for coloring artificial teeth.

Sphene which is of no practical value has been found in Philadelphia, at Frankford; McKinney's quarry, Germantown; in the neighborhood of Easton and Bethlehem; at Van Arsdales limestone quarry, Bucks county; and a number of localities in Chester county.

Rutile has been obtained in very beautiful specimens, and in rather large amount, loose in the soil in the Chester Valley near Parkesburg, and also in Lancaster county; also in West Marlborough, London Grove, Thornbury, West Bradford, and West Nottingham townships, Chester county; in Delaware county in Concord, Middletown, Edgemont, Birmingham and Darby townships. In York county rutile occurs in slender hair-like crystals in quartz in some of the small brooks running into the Susquehanna river, as at Trout Run. The color of rutile is dark brown to bright ruby red, generally in crystals; it has a heavy feel and is shiny like polished metal; it is harder than steel.

Titaniferous hematite has not been observed in the State in large masses as iron ore, and is somewhat rare. Large crystalline pieces have been found in the mica schists of Fairmount Park and elsewhere in Philadelphia; in Delaware county in good sized crystals, at Duttons Mills and Marple and in sands near Media; in Chester county in West Town, Thornbury and East Bradford townships, and in other scattered localities.

TOURBENITE. (See uranium.)

TOURMALINE.

Tourmaline is a complex silicate of alumina and boric acid with the alkalies, such as soda and potash and at times lithium. It is a rather common mineral in the feldspar veins in granites and the mica rocks, and in the Pennsylvania varieties is generally seen as coal-black, longish crystals of a three or six-sided shape. It is a common mineral about Philadelphia in the numerous quarries from Chestnut Hill to Chester; in the rocks in Chester, Delaware, and adjacent counties; and in the crystalline rocks of the lower Susquehanna River region. Tourmaline is of considerable mineralogical interest and in most of its occurrences is of an attractive appearance. When of a proper color, such as pink, green, lavender, etc., it is a valuable gem. No gem qualities have as yet been found in this State.

The gem varieties of tourmaline, such as the pink and green sorts contain the rather rare alkaline element *lithium*. This is not however extracted.

The black variety of tourmaline is at times mistaken for coal, having very much the color and general appearance of the hard coals. It is so much harder, besides being incombustible, that there should be no difficulty in making the distinction between them.

TRAP. DIABASE. GABBRO.

"Trap" is a convenient general term applied to various sorts of dark, heavy, rather fine grained rocks used for road metal, etc. Diabase and gabbro are names in common use among geologists to cover most traps. These are igneous rocks, that is those formed as the result of fusion beneath the surface from the interior heat and have solidified beneath the surface. Some surface lavas are in such large masses that they are very like trap in general appearance. The chief minerals present are pyroxene, plagioclase feldspar, and generally some magnetic iron ore. This makes a very hard, tough rock, used as road ballast, and for similar purposes. The chief uses are for road metal, railroad ballast, heavy wall or abutment material, when crushed as material for concrete, and as top dressing for roads; and in part as material for paving block.

Traps are not used as a general building stone owing to their sombre color and to the difficulty of dressing them with the usual rock tools.

Traps are often confused with *granite;* this is a mistake as true granite is a rock composed of quartz, orthoclase feldspar and mica or hornblende as accessory minerals. Sandstone, slates, and even limestones have been confused with genuine trap rock.

Diabase and gabbro are found as "dykes" in many places in or about the areas of the Triassic rocks; these dykes cut up through the surrounding rocks in masses of variable size and in many places appear as rounded hills or elevations of a picturesque and beautiful character.

Trap Rock is quarried at Gettysburg, Adams county; near Birdsboro, Berks county; Point Peasant and Rushland, Bucks county; Rockville (Fort Hunter), Dauphin county; Glen Mills, Lockley, Radnor and Wayne, Delaware county; Wapwallopen, Luzerne county; Green Lane, Pottstown and Sumneytown, Montgomery county; Marysville, Perry county.

Some of the rock reported as trap at the above localities may not be trap in the strict sense, but some other rock used as such.

URANIUM AND URANIUM MINERALS.

The element uranium in the mineral forms is one of the most interesting of all natural substances. The mineral forms, while rare, are somewhat diverse and in the case of at least one, *uraninite,* are of a remarkable complexity of composition from the extraordinary number of elements contained in it.

Some few years ago the gaseous elements *argon* and *helium,* previously supposed to exist only in the atmosphere of the sun and perhaps in other celestial bodies, were found in the mineral *uraninite* as part of what was formerly supposed to be entirely the gas nitrogen. This is the only known terrestrial occurrence of these two gases.

More recently the so-called X-Rays, and still more recently *radium* have been found to be universally present in uraninite and in practically all uranium minerals. Some further details in regard to this will be given below.

The element uranium, which is a metal, has of late years attracted some attention as one of many elements used to make some special kinds of alloys of steel; it is believed to impart particular qualities of strength and hardness to the steel. In addition "uranium yellow," or sodium uranate, is used to produce the peculiar fluorescent, greenish yellow, tints seen in some glasses and enamels, and to produce an orange or black color in porcelain. A small quantity is used in photographic work.

The uranium minerals are chiefly as follows; all are found in Pennsylvania:

Uraninite.—"Pitch Blende," A uranate of UO_2. Usually also contains lead, calcium, nitrogen (argon, helium), thorium, iron, copper, bismuth, zirconium and other elements. It is the chief "ore" or source of radium. Uraninite is a black, very heavy mineral of a shiny pitch like appearance; it is rarely in crystalline form and is often confused with chromite.

2. *Autunite* is a calcium (lime) phospho-uranium mineral. It is usually seen in bright yellow scales of a pearly lustre.

3. *Torbernite* is a copper phospho-uranium mineral; it is a bright vivid green in color and is generally seen in small squarish plates or pyramids.

4. *Carnotite* is a calcium—potassium vanadium—uranium mineral of the general appearance of autunite with which, in fact, it may be easily confused.

There are other uranium minerals, some of rather uncertain chemical compositon, but the above are the most important.

RADIUM MINERALS.

The subject of radium has become one of the great popular interest and it is worth while to note that some radio-active minerals are found in this State though not in large amount, nor so far in quantity large enough to be of commercial value. Without entering into the very large literature which has grown up around this subject it may be said that radium is almost always found in those minerals which carry the element *uranium*, one of the very rare metals. Other metallic elements such as the cerium group, another series of rare metals; columbium, tantalum and in some cases minerals which carry zinc are found to show some radio-activity.

Radium is extracted by long and careful chemical treatment from the uranium minerals, especially from "pitch-blende" (uraninite). Mr. H. B. Boltwood. (Philos. Mag. April, 1905, p. 599), has analyzed a great many minerals for *radium* and in the following table is given the results of his research; "the activity" is the activity of emanation contained in one gram of the mineral. (See also Min. Res. of The U. S. 1904, U. S. Geol. Surv., Washington, 1905).

LIST OF URANIUM MINERALS EXAMINED FOR RADIO-ACTIVITY.

Substance.	Locality.	Per cent. of uranium.	Activity of emanation.
*Uraninite,	North Carolina,	74.65	150.7
Do.	Colorado,	69.61	147.1
*Gummite,	North Carolina,	65.38	126.7
Uraninite,	Joachimsthal,	61.74	131.8
Uranophane,	North Carolina,	51.68	108.0
Uraninite,	Saxony,	50.64	112.5
Uranophane,	North Carolina,	49.84	88.8
Thorogummite,	......do,	33.17	61.1
*Carnotite,	Colorado,	22.61	41.6
Uranothorite,	Norway,	11.38	24.9
*Samarskite,	North Carolina,	10.44	23.2
Orangite,	Norway,	10.34	22.84
*Euxenite,	......do,	8.71	19.8
Thorite,	......do,	7.54	15.6
Fergusonite,	......do,	5.57	11.95
Aeschynite,	......do,	4.52	9.98
Xenotime,	......do,	.70	1.14
*Monazite,	North Carolina,	.43	.88
Do,	Norway,	.41	.84
Do,	Brazil,	.31	.76
Do,	Connecticut,	.30	.63
*Allanite,	North Carolina,	.007	.014

The minerals marked * have been found in Pennsylvania, though not in large quantity; also a number not mentioned by Boltwood have been found in this State. Dr. E. T. Wherry has gone over the list of Pennsylvania localities with great care and has published in *The Journal of The Franklin Institute, Phila., January, 1908,* a long list of such minerals found in Pennsylvania.

We quote as follows from Dr. Wherry's article: "In the State of Pennsylvania, and especially in the southeastern portion, uranium-bearing minerals are by no means uncommon. At present writing some fifty localities are known from which nearly twenty different species have been obtained, and every now and then new finds are reported. These occurrences are confined almost exclusively to the areas of highly metomorphosed schist and gneiss of our region, being especially numerous where pegmatites are developed, as in Southern Delaware county, although they are not infrequent in the city of Philadelphia itself." (See Jour. Franklin Inst., Vol. CLXV, No. 1, Jan., 1908, page 60).

Uraninite is found in Fairmount Park; at Chester, Avondale, Swarthmore in Delaware county. Autunite and torbernite have been found in practically the same localities, and in addition at Frankford, Broad and Olney streets, Wingohocking, Germantown, and other places in Philadelphia. In the gneisses and mica schists along Crum Creek all of these and other uranium minerals have been found. For more detailed localities references may be made to Dr. Wherry's article.

CARNOTITE.

Carnotite has been discovered in Pennsylvania by E. T. Wherry, (The American Journal of Science, Vol. XXXIII., p. 574, June 1912). We quote as follows:

"In Genth's Mineralogy of Pennsylvania autunite was stated to "have lately been found in a conglomerate from the neighborhood of Mauch Chunk," the exact locality being, however, unknown. Specimens labeled similarly are included in several of the old collections of Pennsylvania minerals, but a study of these and of a considerable quantity of material collected at what is probably the original locality, the eastern end of Mt. Pisgah, immediately north of the town of Mauch Chunk, has shown that the mineral in question is really to be classed as carnotite.

"The carnotite occurs in scattered streaks and patches throughout the lower portion of the conglomerate, not extending far above the last red shale layer, although ledges of conglomerate continue to be exposed 600 feet farther to the summit of the ridge. As the road turns westward, gradually rising across the beds, the layer containing it can be followed to a distance of 2,000 feet, but then disappears beneath the roadway, and no trace of the mineral could be found at the corresponding horizon where again exposed near Tamaqua, 10 miles further west.

"The analytical results are given in the first column of the accompanying table, and the figures obtained by deducting the insoluble matter, iron oxide and water, and recalculating the remainder to 100

per cent., in the second. The iron is certainly present as limonite, and while a part of the water may belong to the carnotite, the amount in this form is indeterminate."

	1.	2.	Ratios.		
V_2O_5,	7.2	21.1	.116		1.00
UO_3,	23.8	69.8	.243		2.09
Fe_2O_3,	6.1	....			
CaO,	1.5	4.4	.079	.129	1.11
K_2O (diff.),	[1.6]	4.7	.050		
H_2O,	10.5	....			
Insoluble,	49.3	....			
	100.0	100.0			

WAVEILITE. (See phosphate minerals.)

WULFENITE.

This is a lead mineral, the molybdate, not important. Found at Phoenixville.

ZINC. (See lead and zinc.)

ZIRCON.

A mineral consisting of the oxides of silicon and zircon, or more probably of zirconium silicate.

It has been seen in The South Mountain in Berks and other counties. It is somewhat radio-active. (See uranium).

Zircon also has been suggested as a possible source of material for mantels, such as the Welsbach type.

It has been found at a number of places all in the western part of the State. It has no commercial value in Pennsylvania.

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